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EDITORIALS

CHEMISTRY AND AGRICULTURE

In universities in the United States, chemistry has always been considered as the scientific basis of agriculture. In our National University while we have diverged from this practice by considering plant physiology the basis of agronomy, a very logical thing to do since agronomy is or should be considered as applied plant physiology, we still regard our chemistry work as a matter of very great importance. In a previous number of the *Agriculturist* (*Philippine Agriculturist and Forester*, Vol. V, No. 1, p. 7) an exposition of our work in chemistry was given. Since that date a number of contributions to the chemistry of our agricultural products has been added.

A great extension in our Department of Chemistry has been made necessary by the offering of the new courses in sugar technology, which have been organized in response to the demand for sugar technologists by the many centrals that are now being erected in different parts of the Islands. In the past, work in chemistry was limited to a year's teaching in the freshman year, followed by another course in the application of chemistry to agriculture; at present we are offering thirteen courses in General, Analytical, Industrial, Organic and Biological Chemistry. Most of these courses are required of students desiring to qualify as sugar chemists and a number are required of students in the other courses in Agriculture and in the College of Veterinary Science and the School of Forestry.

The Experiment Station Chemistry work is a subject of very great importance to this department as well as to the other departments of the College. In the words of Professor Copeland, "Experimentation in many phases of Agronomy is quite impossible without the collaboration of the chemist". For the knowledge of the inorganic constituents of plants would indicate their fertilizer requirements, while the composition of soils in correlation with the study of soil types and the results of plot experiments would often indicate the kind of treatment given localities should receive to grow certain crops successfully. The value of commercial fertilizers to the farmer can be determined only by knowing their content of potassium, phosphorus, and nitrogen or their content of calcium oxide, the elements one buys fertilizer for. The percentages of these elements in the fertilizers can not be determined without the help of the chemical analyst.

Knowledge of the composition of the different varieties of sugar cane is essential for the determination of their agronomical values. In many cases the production of crops is, in the last analysis, the production of chemical substances, (sugar, oil, camphor, essential oils, starch, etc.), and knowledge of the amount of these constituents contained by the different varieties of plants under different treatments would indicate what varieties and what treatment would yield the largest profit under a definite set of conditions.

The chemist should be particularly helpful in the study of the utilization of farm waste products. The right disposal of these would make farming more profitable. The history of industrial development in the world is replete with instances in which the right utilization of the waste products turned the industry from a losing to a profit-making proposition. Questions connected with the utilization of straw from rice fields; shells, husks, and water from coconuts; the strippings from our abaca; the black strop molasses and bagasse ash from the centrals are full of potential possibilities.

In feeding work in Animal Husbandry, knowledge of the chemical composition of the feeds is essential for securing the most economical results. Recent results of nutrition studies may have a certain influence on the kind of crops that should be grown for food. For obvious reasons certain food crops are grown more easily than others. These are usually the cheapest. Man follows the mode of nature in partaking of the greatest variety of foods available in his attempt to insure for his body all the food constituents necessary for his well-being. The methods of nature, blind as they are, are not the most efficient nor economical. A knowledge of what constitutes a complete food will enable dietitians to make the most economical and efficient combination and thus avoid waste. It will tell farmers what crops are the most desirable sources of these constituents so that they may direct their efforts for their efficient production. A system of farming would then be developed whereby the most desirable crops necessary to supply the market with these constituents the year around, would be grown in rotation.

The fact that the composition of agricultural products vary from season to season and in localities, makes it necessary that the chemist should constantly be "on the job" determining these changes in composition and establishing relations between composition and different conditions, or else establishing limits of composition from one set of conditions to another.

The chemistry work of the Experiment Station has two distinct characteristics: one involves the study of present methods of analysis in their application to local problems, or the development of new ones; and the other involves the use of these methods in the gathering of data and the establishment of new facts in agricultural science. Both of these are essential functions of a department of Chemistry.

In any department of human endeavor success is insured through proper organization coupled with the right kind of personnel and the right kind of a man at the head of it. While the question of the right head is more or less subject to chance, the proper organization can be secured by following general sound principles and a logical arrangement of Divisions. An *esprit de corps* should be developed among the different members of the Divisional staffs as it would insure complete co-operation and co-ordination of work. While topical work should be assigned to each division, which would then be held as the local authority in its field, and the logical promoter of investigation along its line, it should be understood that no sharp lines of demarcation should be followed in the nature of the problems that may be undertaken by each member of the staff, but that complete co-operation should at all times predominate between the several Divisions.

MANUEL L. ROXAS,
Of the Department of Agricultural Chemistry.

EUROPE'S YOUNGEST REPUBLIC ESTABLISHES A SUGAR STATION

For the past years the College of Agriculture has been advocating the establishment of a central Experiment Station in Los Baños, where among other things sugar problems confronting our local industry could be worked out. In this connection it may be of interest to our readers to know what other countries are doing along this line. One of the young republics, Czechoslovakia, whose existence was brought about by the last and greatest world war, and which, in the words of S. G. Ruegg, is "showing more constructive political, industrial and agricultural statemanship than any of the nations emerging from the war," has decided to "have the most up-to-date sugar experiment station in Europe". This station is now in process of construction. What the station promises to be may be gathered from the following taken from S. G. Ruegg's article in the *Louisiana Planter* (June 18, 1921).

The experiment station will have a fine dwelling for the director; a home for the gardeners; and for the mechanics; a garage; and a large hot-house for vegetation. It is planned to enclose the grounds with an artistic iron fence, with a magnificent gate.

"The main experiment station will have many departments. In the cellar, which receives light from without because of its admirable location, the workmen will have special facilities. The machine depot will have a crane, there will be a room for the distillery and there will be a boiler room for the distillery with high and low pressure steam, with apparatus to relime water. The sample room, where beets are tested, will have a large space to wash beets, and these are then lifted into the terrain of the laboratory. There will be a foundry to cast needed parts and a chemical oven. There will be a room for the gas "bombs," a ventilation chamber, a depot for coal, chemicals, glass, alcohol, a crystallization room and an elevator with its motive power.

"In the southern terrain there will be the machine shop, a material department, a large room for experiments and a moving crane. The machine shop will be electrically equipped, there will be apparatus to compress air, an ice plant and liquid air apparatus. The room for preparing the beets will have the usual polariscopes and there will be arrangements to handle mass selections or individual beets. There will be a laboratory for experiments for visiting guests, American sugar experts, if you please. There will be a fine residence for the fireman and overseer of the whole institute. A large room for microphotography is also in the plan. There will be bath rooms for shower baths for employees.

"The first story of the main building will be devoted to laboratory work on beets, there will be special rest rooms for those at work. There will be an architect's room in the first story also. The administration rooms will also be here with telephone. In the second story will be found the phytopathological department with samples, cabinets and show cases. The technical chemical department will be located here; there will be galleries where open demonstrations can be held. There will be general study rooms, places for elementary analysis, library room, etc.

"In the second story there will be a large dark room for developing films—the bacteriological section will be placed here. The physical-chemical department will be found on this floor, electro-chemical machines and kolloid labo-

ratories, with special rooms for the workers. In the upper story will be a store room with ventilation apparatus and things incidental to the whole situation can be placed in this upper floor. The whole grounds will be beautified and it is safe to say that from this center will emanate light and life in the beet industry the like of which has never been witnessed in the new republic. It is believed that ere many years the land will produce 1,000,000 tons of sugar. At the present time the Czecho-Sloviak republic is running close on to 700,000 tons a year. The sugar fraternity all over the world will watch the new throne of information with great interest, while they send forth good will to their brothers in the art of sugar manufacture."

MANUEL L. ROXAS,
Of the Department of Agricultural Chemistry.

A BIOLOGICAL STUDY OF COPRA MEAL[1]

By Antonio Derecho

EIGHT CHARTS

Extensive and exhaustive studies on copra meal are not many and some of the few that are on record seem to have given contradictory results. Halliburton and Drummond (1) in an experiment with rats concluded that coconut oil contains little or none of the fat-soluble A. This conclusion was confirmed by Jansen (2). Johns, Finks, and Paul (3), on the other hand, claim that copra meal contains enough of water-soluble B and some fat-soluble A. They further state that copra meal contains enough protein to produce almost a normal rate of growth and that coconut globulin is satisfactory as a sole source of protein. Van Kampen (4) reports that copra meal contains 17.5 per cent of sugar. This was determined polari-metrically and calculated as sucrose.[2] Coconut oil is used extensively in the manufacture of oleomargarine (5).

In this laboratory, Santos (6) analyzed copra meal and gave the following composition:

Moisture	11.3
Oil	12.2
Crude protein	20.1
Ash	5.5
Crude fiber	13.3
Carbohydrates	37.3

The proteins gave on hydrolysis arginine, histidine, lysine, and cystine, in fair amounts. From its chemical composition one may conclude that copra meal is a good food, well balanced, and contains amino acids which are among the acids most essential for life. Lysine, which Hogan (7) claimed to be essential for growing animals is present.

MATERIALS AND METHODS

The animals used in this work were guinea pigs. They were divided into 14 lots; two animals in each lot, except in certain cases indicated later in this paper. Each lot was placed in cages 70×70×70 centimeters. The floor of the cages was made of boards perforated at distances of 10 centimeters for drainage of urine and water. The walls were of two-centimeter meshed wire.

PREPARATION OF FEED

Copra cake as it came from the factory was finely ground to a meal by passing it through a grinder. The finely ground meal was then passed through a one-millimeter sieve.

The cassava starch used in Lots 1, 2, 3, 4, 5, and 6 was practically free from impurities. For Lots 7, 8, and 10 dextrin was used instead of cassava starch.

[1] Thesis presented for graduation from the College of Agriculture, No. 121; Experiment Station contribution, No. 51.

[2] A paper by Caray published in this issue gives a complete analysis of copra meal.

All chemicals desired not being available McCollum and Davis (8) salt mixture 308[3] was slightly modified for Lots 1, 2, 3, 4, 5, and 6 by substituting Na_2HPO_4 for K_2HPO_4. For Lots 7, 8, and 10 the complete salt mixture was used.

The water extract of egg yolk was prepared according to McCollum and Davis (9) method. Eggs were first boiled to coagulate the albumin portion. The yolk thus separated was dried in an oven at 38°-50° C. The dried egg yolk was weighed, treated with water, thoroughly stirred, and filtered four times by suction. The emulsified fat going with the filtrate was removed by shaking the filtrate once with ether; then the ether was separated by means of a separating funnel. The fat-free filtrate was refiltered and then dried on weighed cassava starch or dextrin.

Butter fat was prepared according to Osborne and Mendel's method (10). Butter of high quality was melted at 35°-45° C in a water bath. The melted butter was then centrifuged for one hour and the top layer of butter fat separated.

Casein manufactured by Merck and Co. was used without further treatment.

The agar-agar used for Lots 7 and 8 was finely cut into pieces before mixing with the feed.

Guinea grass (*Panicum maximum*, Jacq.) was used for the green feed. For a short time, however, when there was shortage of guinea grass, *Paspalum conjugatum*, Borg. was employed for Lot 15. For Lot 9 the guinea grass was dried in a copra drier for 14 hours at temperatures ranging from 60° to 80° C.

The dried grass was chopped into pieces fine enough to pass through a one-millimeter sieve. The orange juice was extracted by hand and filtered once through cloth. Distilled or rain water was used for drinking.

The final preparation of the rations was made by weighing the different constituents and mixing them thoroughly. This prepared feed was given the animals dry in petri dishes.

To give bulk to the ration, lots without grass were given quantitative filter paper during the first week or two; usually the animals quit eating the paper after the second week. The filter paper was free from any nutritive constituent likely to materially affect the results.

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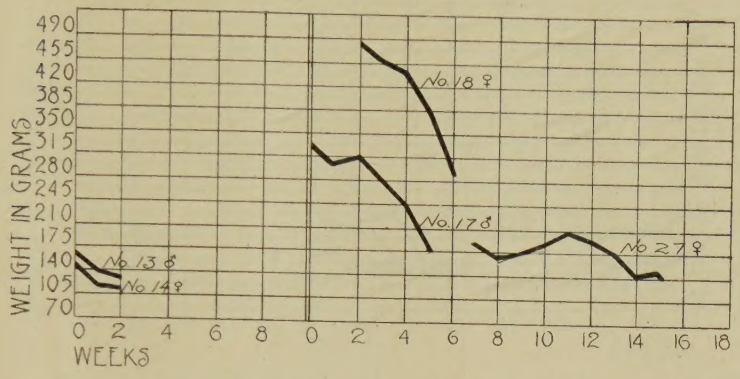
[3] McCollum and Davis salt mixture 308 has the following components:

NaCl	5.00 g.
K_2HPO_4	12.10
$CaH_4(PO_4)_2$ plus H_2O	2.56
Ca lactate	29.44
Fe citrate	1.00

CHART I.—*Showing curves of growth of animals in Lots 1 and 2.*



LOT 1.—Ration:
Copra meal *ad libitum*.

LOT 2.—Ration:

Copra meal	67 gm.
Cassava starch	19 gm.
Salt mixture 308 (M & P) modified	4 gm.
Butter fat	5 gm.

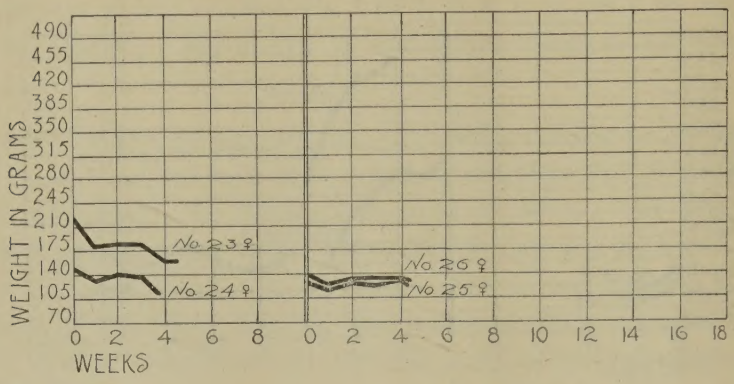
Water extract of 5 gm. dry egg yoke.

Lot 1 was fed exclusively with copra meal. The animals gradually grew weak, arched their backs, were highly constipated, and could not live longer than three weeks. (See Chart I, Lot 1.)

Lot 2.—Copra meal, supplemented with cassava starch, salt mixture, butter fat, and water extract of egg yolk, could not support the life of guinea pigs. The animals were constipated, developed scurvy, and urinated profusely. Difficulty of eliminating the feces was so severe that congestion followed and blood passed out with the sticky and pasty feces. Postmortem examination revealed hemorrhages around the region of the cecum and rectum. Hess and Unger (11) produced scurvy in guinea pigs on a diet of hay, oats, and water. Addition of boiled egg effected no cure. (See Chart I, Lot 2.)

Lot 3.—As has been stated, Johns, Finks, and Paul (3) believe that copra meal had enough water-soluble B. To verify their contention, this lot was given copra meal, cassava starch, casein, salt mixture, and butter fat. After the third week the animals were constipated, the feces became sticky, and scurvy developed. With animal No. 24 the case was more serious because in the effort of the animal to void its dung a portion of the rectum was everted. Hemorrhage was very conspicuous around the cecum and rectum. With the idea of finding out the effect of orange juice on constipation and scurvy, on the 24th day of the experiment 5 cc. of orange juice were given animal No. 23. For a time the animal seemed to recover, but it gradually grew weak and died 9 days after the beginning of the administration of the orange juice. No hemorrhage was noticed as with animal No. 24, showing the peculiar property of orange juice in preventing severe congestion. Due to constipation and the development of scurvy it was hard to conclude from this experiment whether copra meal contained or lacked water-soluble B. (See Chart II, Lot 3.)

CHART II.—*Showing curves of growth of animals in Lots 3 and 4.*



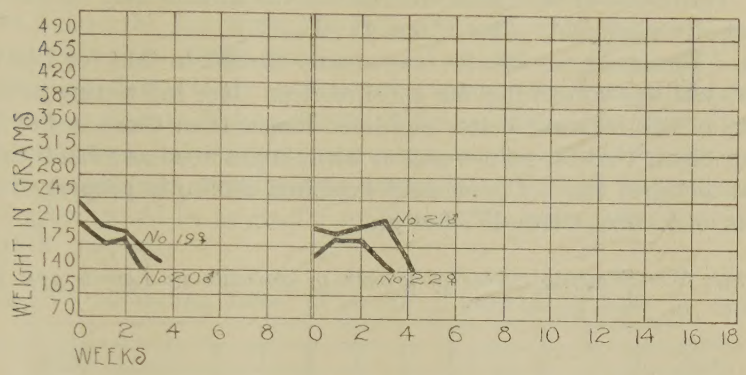
LOT 3.—Ration:		LOT 4.—Ration:	
Copra meal	67 gm.	Copra meal	67 gm.
Cassava starch	19 gm.	Cassava starch	19 gm.
Casein	5 gm.	Casein	5 gm.
Salt mixture 308 (M & P) modified	4 gm.	Salt mixture 308 (M & P) modified	4 gm.
Butter fat	5 gm.	Water extract of 5 gm. dry egg yoke.	

Lot 4.—The contradictory results obtained by different investigators placed the exact nature of copra meal in an uncertain category. With the object of testing for the presence of fat-soluble A, this lot was given copra meal, cassava starch, casein, salt mixture, and water extract of egg yolk. The animals developed exactly the same disorders as those in Lot 3. To give the same treatment as for Lot 3, 5 cc. of orange juice were given each animal daily. As in Lot 3 the animals seemed to recover, but both died after 9 days. Again, in these animals the property of orange juice in preventing hemorrhage was shown. The difference between this lot and Lot 3 was too slight to warrant any conclusion. But there seemed to be an indication (see Chart II, Lot 4) that the ration for Lot 4 was more complete than that for Lot 3.

Lot 5.—Mineral salts are essential for growing animals and a feed before it can be satisfactory must contain them in the right proportion. To test the nature of the salts in copra meal, this lot was given copra meal, cassava starch, casein, butter fat, and water extract of egg yolk. The same disorders developed in the animals as in Lot 2. Again, since constipation and scurvy were apparently the cause of the death of the animals, conclusion as to the quality of the mineral salts is reserved. (See Chart III, Lot 5.)

Lot 6.—All the lots in these experiments lacked either one or more of the essentials of a good food. To study the behavior of guinea pigs when given a complete food with copra meal as the basal ration, this lot was given copra meal, cassava starch, casein, salt mixture, butter fat, and water extract of egg yolk. Animal No. 21 gained in weight in two successive weeks which seemed to indicate some good quality in the ration. However, the animals developed the same disorders encountered in Lots 2, 3, 4, and 5. Hemorrhage around the cecum and rectum was pronounced. This showed that even with complete food with copra meal as the basal ration, guinea pigs could not live, and that some unknown substance, the absence of which is responsible for the development of scurvy, is lacking in copra meal. (See Chart III, Lot 6.)

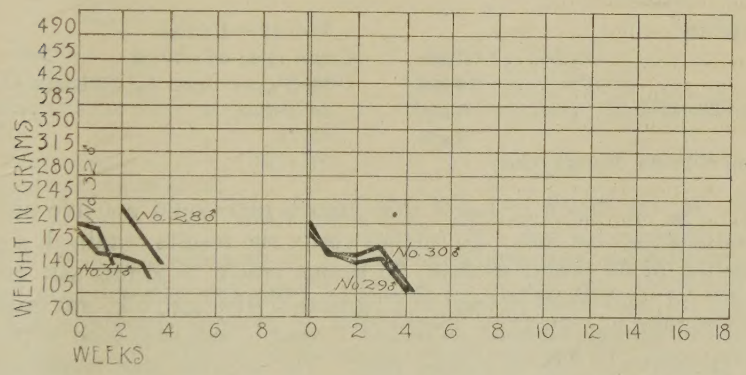
CHART III.—*Showing curves of growth of animals in Lots 5 and 6.*



LOT 5.—Ration:	
Copra meal	67 gm.
Cassava starch	19 gm.
Casein	5 gm.
Butter fat	5 gm.
Water extract of 5 gm. dry egg yoke.	

LOT 6.—Ration:	
Copra meal	67 gm.
Cassava starch	19 gm.
Casein	5 gm.
Salt mixture 308 (M & D) modified	4 gm.
Butter fat	5 gm.
Water extract of 5 gm. dry egg yoke.	

CHART IV.—*Showing curves of growth of animals in Lots 7 and 8.*



LOT 7.—Ration:	
Polished rice	64.0 gm.
Casein	13.4 gm.
Salt mixture 308 (M & D)	2.4 gm.
Butter fat	5.0 gm.
Dextrin	13.2 gm.
Agar-agar	2.0 gm.
Water extract of 5 gm. dry egg yoke.	

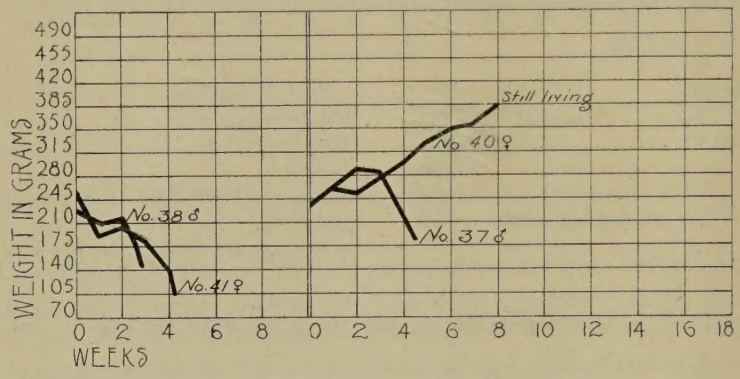
LOT 8.—Ration:	
Copra meal	64.0 gm.
Casein	13.4 gm.
Salt mixture 308 (M & D)	2.4 gm.
Butter fat	5.0 gm.
Dextrin	13.2 gm.
Agar-agar	2.0 gm.
Water extract of 5 gm. dry egg yoke.	

Lot 7.—McCollum and Davis (8) succeeded in raising rats with 64 grams polished rice, 13.4 grams casein, 2.4 grams salt mixture, 5 grams butter fat, 13.2 grams dextrin, 2 grams agar-agar, and water extract of 5 grams of wheat embryo. This ration was slightly modified by substituting water extract of 5 grams of dry egg yolk for 5 grams of wheat embryo, and used for the guinea pigs in this lot. To the surprise of the writer two of the three animals died in less than two

weeks. At first the animals voided their dung normall, but later they were constipated. The failure of this ration to maintain the animals may be due to a lack of antiscorbutic vitamine[4]. (See Chart IV, Lot 7.)

Lot 8.—The ration for this lot was exactly similar to that for Lot 7 except that copra meal was substituted for polished rice. It is interesting to note that the animals in this lot grew better and lived longer than those in Lot 7. This seemed to indicate that for guinea pigs at least, copra meal as a basal ration was better than polished rice. Copra meal exhibited scorbutic property in this as in previous lots. (See Chart IV, Lot 8.)

CHART V.—*Showing curves of growth of animals in Lots 9 and 10.*



LOT 9.—Ration:	
Dextrin	60 gm.
Casein	25 gm.
Salt mixture 308 (M & D)	5 gm.
Butter fat	8 gm.
Water extract of 10 gm. dry egg yoke.	

LOT 10.—Ration:
Copra meal *ad libitum*.
Guinea grass dried for 14 hours at 60°-80°C. *ad libitum*.

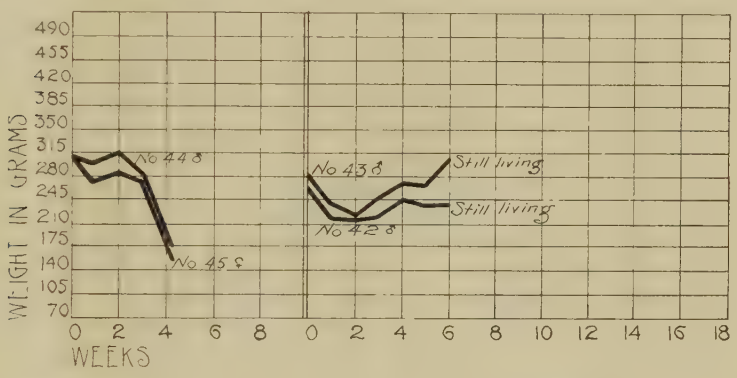
Lot 9.—It was shown in Lot 7 that guinea pigs could not live on a ration that was satisfactory for rats. To further verify the results obtained, a complete food consisting of 60 grams dextrin, 25 grams casein, 5 grams salt mixture, 8 grams butter fat, and water extract of 10 grams of dry egg yolk, was given. The behavior of the animals showed, as in Lot 7, that a complete food without grass could not support the life of guinea pigs. The animals had constipation, developed scurvy, and the cecum was full of feces. Hemorrhage around the cecum and rectum was serious. This and Lot 7 suggested that for the maintenance and growth of guinea pigs some unidentified substance (11) (antiscorbutic vitamine?) was essential for the proper working of the system of guinea pigs. (See Chart V, Lot 9.)

Lot 10.—Lot 15 was given copra meal and green guinea grass and the animals manifested excellent health and rate of growth. To study the difference in food value between green and dried grass, guinea grass dried for 14 hours at temperatures between 60° and 80° C. was substituted for green guinea grass in Lot 10. Animal No. 37 increased in weight during the first two weeks, but later it gradually decreased in weight and finally died on the 31st day. The decline in health and

[4] This work was undertaken in the early part of 1919. While it was being completed a great number of contributions giving strong evidence of the existence of an antiscorbutic vitamine in foods were published. Drummond, *Lance*, 1918, ii, 482, proposed to call it "Water Soluble C".

decrease in weight was attributed to the heavy service the animal made when No. 40, a female, was placed with it at the beginning of the second week. Animal No. 40 lost weight the first week, but gained weight in six successive weeks, and is still living (March 6, 1920) and is in good condition. If animal No. 40 continues to live, which it is likely to do, this lot would prove that drying green grass even at a temperature as high as 80° C. would not materially affect its nutritive, value, an indication that the unknown substance responsible for the prevention of scurvy in guinea pigs would not be destroyed at 80° C. It would also prove that dried grass would be as good a supplement as green grass for copra meal. (See Chart V, Lot 10.)

CHART VI.—*Showing curves of growth of animals in Lots 11 and 12.*



LOT 11.—Ration:

Period 1. Copra meal..... 80 gm.
Guinea grass dried for 14 hr. at 60°-80°C..... 20 gm.
Period 2. Copra meal..... 66⅔ gm.
Guinea grass dried for 14 hr. at 60°-80°C..... 33⅓ gm.

LOT 12.—Ration:

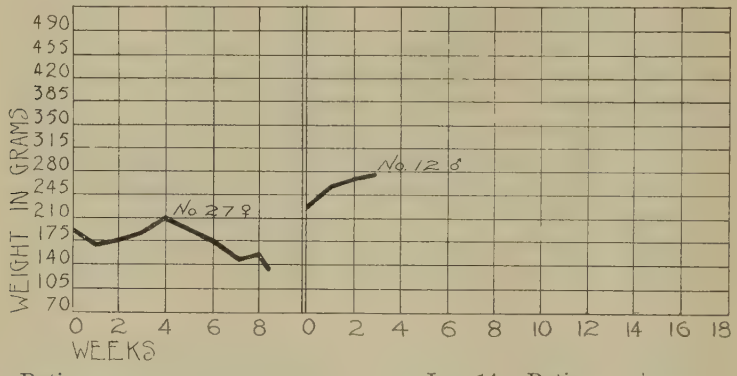
Copra meal *ad libitum*.
Orange juice, daily for each animal.... 5 cc

Lot 11.—There seemed to be a good supplementary relationship between copra meal and dried guinea grass as shown by animal No. 40 in Lot 10. To find out the minimum amount of dried grass necessary to supplement copra meal and support life, a ration of 80 grams copra meal and 20 grams dried guinea grass was given. At first the animals looked as though they would thrive well, in the second week they gained weight. But they gradually became constipated. In the fourth week the dried grass was increased to 33⅓ grams and the copra meal decreased to 66⅔ grams. This change did not relieve constipation. The feces became sticky and pasty and scurvy developed. The results showed that even 33⅓ per cent of dried guinea grass was not sufficient to keep copra meal-fed guinea pigs free from scurvy. (See Chart VI, Lot 11.)

Lot 12.—Guinea pigs are grass-eating animals and Lots 7 and 9 showed that without green grass they could not live even with a complete food. To test further the validity of the above results and to study the supplementary relationship between copra meal and orange juice, each animal in this lot was fed copra meal and 5 cc. of orange juice daily. The animals were active and although they lost weight the first two weeks they gained in the third and fourth weeks. In the fifth week both animals lost weight; in the sixth week animal No. 43 gained in

weight and No. 42 maintained almost its weight. This lot (if the animals continue to live) may prove that the development of scurvy in guinea pigs is not at all due to the physical character of the food, as may be deduced from the results in Lots 7 and 10, but to some unknown substance present both in the leaves of guinea grass and orange juice. If the animals should die there would be either some insufficiency in the ration or the 5 cc. of orange juice given each animal daily does not contain enough of the antiscorbutic substance to entirely prevent scurvy. The antiscorbutic property of orange is attributed by McCollum and Pitz to the presence of sodium and potassium citrates which have laxative properties, although Harden and Zilva (12) tried to disprove this by the fact that just as good antiscorbutic extract was obtained even after all the citric acid had been removed. (See Chart VI, Lot 12.)

CHART VII.—*Showing curves of growth of animals in Lots 13 and 14.*



LOT 13.—Ration:

Period 1. Copra meal	67 gm.
Cassava starch	19 gm.
Salt mixture 308 (M & D) modified	4 gm.
Butter fat	5 gm.
Water extract of 5 gm. dry egg yoke.	
Period 2. Same as period 1 plus orange juice, daily to each animal	2 cc.

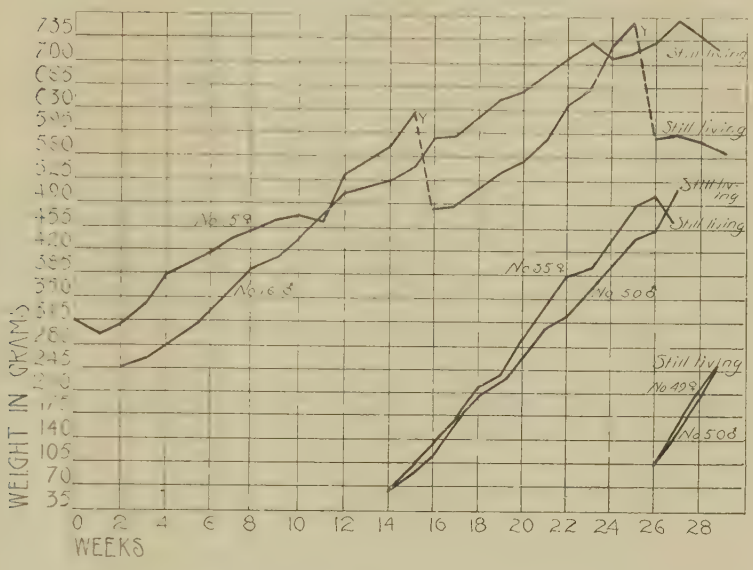
LOT 14.—Ration:

Copra meal	50 gm.
Rice bran	50 gm.
Green guinea grass *ad libitum*.	

Lot 13.—The ration for this lot differed from that for Lot 2 only in having 2 cc. of orange juice given daily, beginning on the 17th day of the experiment. For three successive weeks the animal gained weight, then it gradually became weak and died. There was no hemorrhage although the cecum was full of feces. Whereas 35 was the maximum number of day the animals in Lot 2 lived, animal No. 27 in this lot lived for 59 days, the difference in length of life might be attributed to the addition of orange juice in ration. Although it prolonged the life of the animal, 2 cc. of orange juice were not sufficient to keep the animal entirely free from scurvy. (See Chart VII, Lot 13.)

Lot 14.—The feed used for the general multiplication lot of guinea pigs in this college was composed of copra meal, rice bran, and green guinea grass. The same feed was given Lot 14 and it was to be expected that the animals would exhibit a normal rate of growth. That this was the case was shown by the rate of growth of animal No. 12 which was kept under exactly the same condition as those in other lots. The animal was healthy both at the beginning of the experiment and at this writing (March 6, 1920). (See Chart VII, Lot 14.)

CHART VIII.—*Showing curves of growth of animals in Lot 15.*



LOT 15.—Ration:
Copra meal *ad libitum.*
Green guinea grass *ad libitum.*

Lot 15.—The difference between the leaf of the plant and the endosperm of seeds is due to the fact that the endosperm is mostly stored food while the leaves of plants are active cells and with very little stored food (13). Consequently, the active nutrient in the leaf is all due to the living cells and not to the dead cells containing starch and protein. Lot 15 was given nothing but copra meal and green guinea grass with the object of studying the supplementary relationship between these two feeds. The general vigor of the animals, the rapid rate of growth and the reproduction of young (twice during the period from August 16, 1919, to February 14, 1920) all showed that copra meal and green guinea grass in the proportion of 3 per cent copra meal and 97 per cent green guinea grass, or 16 per cent of the solids in the green leaves by weight formed a satisfactory combination for guinea pigs. (See Chart VIII.)

SUMMARY OF CONCLUSIONS

1. Copra meal alone or even when supplemented with purified food was highly constipating, at least for guinea pigs. This constipation and retention of feces in the cecum caused congestion and hemorrhages around the cecum and rectum. Scurvy then developed.

2. Green guinea grass and copra meal were excellent supplementary feeds and they could maintain the weight, promote growth, and reproduction in guinea pigs.

3. Without an antiscorbutic vitamine, copra meal could not be supplemented with purified food even with fat-soluble A and water-soluble B, and maintain the life of guinea pigs. This antiscorbutic vitamine was found in guinea grass and in orange juice.

4. Although guinea grass dried at 60°-80° C. given *ad libitum* seemed to satisfactorily supplement copra meal, 20 per cent or even 33⅓ per cent of this in a ration of copra did not contain sufficient antiscorbutic vitamine to keep guinea pigs free from scurvy.

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THE CHEMICAL COMPOSITION OF COPRA MEAL WITH SPECIAL REFERENCE TO THE NATURE OF ITS CARBOHYDRATES[1]

By Elias M. Caray

A survey of the literature on copra meal shows that very little has been done in the study of its chemical nature. Lindsey (1), in connection with feeding experiments with dairy cattle, reported the following percentage composition of copra meal: water 9.00, protein 19.35, fat 9.12, extract matter 48.00, fiber 8.64, and ash 5.89. A few analyses made at various State Agricultural Experiment Stations (2, 3, 4) showed approximately the same composition except in the oil content. The percentage of oil varies according to the process of oil extraction. The following shows, in part, the percentage composition of the copra meal produced in the Philippines, as compiled by the Division of Organic Chemistry, Bureau of Science (5): ash 5.9, crude fiber 9.5, protein 19.9, moisture 5.38, free fatty acids calculated as oleic acid 7.8, and oil 12.5 in the expeller product and 5.0 in the hydraulic press product.

Lindsey (1) reported the following coefficients of digestibility of copra meal from his digestion experiments with sheep: protein 90, fat 100, extract matter 87, fiber 23, and ash 64 per cent. He demonstrated that as supplementary feed for dairy cattle, copra meal and gluten feed gave about the same yield of milk, but that the milk produced with copra meal contained more butter than that produced with gluten feed. Cranfield (6) showed that when copra meal replaced other concentrates for dairy cattle, a richer milk which produced butter of a better keeping quality and of a firmer texture was obtained. The same result was obtained by Skelton (7), Carlier (8), and Ewing and Spence (9). Fingerling (10) claims that copra meal contains substances that have a stimulating effect on the mammary glands of milch goats.

Johns, Finks, and Paul (11), in their feeding experiments with rats, showed that copra meal contains enough water-soluble and a sufficient quantity of protein with some fat-soluble vitamines present to promote an almost normal growth. They also found that calcium, phosphorus, and chlorine were present in insufficient quantities. Santos of this laboratory (12) studied the protein content of copra meal and found fairly large quantities of the amino-acids which are essential for life and growth. He was able to dissolve only 47.55 per cent of the actual amount of protein nitrogen present. Derecho[2], working with guinea pigs, on the other hand, demonstrated that copra meal when supplemented with purified feeds including fat-soluble and water-soluble vitamines could not keep the animals alive without the addition of antiscorbutic vitamine which was found in guinea grass and in orange juice. He concluded that guinea grass and copra meal were excellent supplementary feeds for guinea pigs.

No particular mention has yet been made of the nature of the carbohydrate content of copra meal. The one report made on the subject was that

[1] Thesis presented for graduation from the College of Agriculture, No. 122; Experiment Station contribution, No. 52.

[2] Derecho, Antonio. A biological study of Copra meal. ***Philippine Agriculturist.*** ***10:*** 45-54, 1921.

of Van Kampen (13) who gave 17.5 per cent as the sucrose content of the product, obtained by polarization. An idea of the sugar content of copra meal may be had from the analysis of four samples of copra by Bodmer (14). The percentages of dextrose and sucrose in the four samples analyzed ranged from 0 to 2.4 and from 0.95 to 7.71, respectively. Santos (12), in connection with his study of the protein of copra meal, determined the total carbohydrates and found it to be approximately 37 per cent, not including the crude fiber.

It is thus seen that over one third of the total constituents of copra meal is carbohydrates. A full knowledge of the nature of these carbohydrates is essential for a complete understanding of the nutritive value of the meal.

The writer aims to present in this paper the results of his work on (*a*) proximate analysis of copra meal, (*b*) the identification of the carbohydrates, and (*c*) the determination of the relative amounts of the important carbohydrates present.

MATERIALS

Two kinds of copra meal are produced in the Islands, the hydraulic press product and the expeller product. The latter differs from the former in that it has a greater oil content. The copra meal used in this experiment was an expeller product, purchased by the Department of Animal Husbandry of this College from the Philippine Vegetable Oil Company of Manila in May, 1920. It was about six months old when analyses were made.

In sampling, small representative portions were obtained from each of about thirty sacks of the commercial product. These were mixed together and by the method of quartering a portion was obtained for analysis. It was ground to a fine powder in a mortar, then passed through a one-half millimeter sieve to make the sample as uniform as possible. It was then divided into fourteen sub-samples each of which was analyzed separately.

METHODS OF ANALYSIS

PROXIMATE ANALYSIS

Proximate analysis was made of the fourteen sub-samples to determine the general composition of the material. The methods employed in this analysis were in general those recommended by the Association of Official Agricultural Chemists (15), with slight modifications.

Moisture.—Five grams of the material were dried in a hot-water oven at 98°-99°C for four hours. The loss in weight was considered moisture.

Ash.—A weighed portion of the material was charred in a platinum crucible and then heated to low redness till the ash was grayish white.

Water-soluble free organic acids.—A weighed sample was extracted with water for one hour and the extract titrated with standard alkali and the titre was calculated as oleic acid (16).

Fat.—A weighed sample of the dry material was extracted with anhydrous ether in a Soxhlet's extractor for twelve hours. When the residue from this treatment was treated with water for free acid it was found that the aqueous extract was neutral. This showed that the water-soluble free organic acids were also extracted by the ether. The percentage of water-soluble free acids as determined above was therefore subtracted from the percentage of the total ether extract and the difference taken as the percentage of oil.

Fiber.—Two-gram portions of the dry material were boiled for thirty minutes successively with 1.25 per cent solution of sulphuric acid and 1.25 per cent solution of sodium hydroxide. The residue was dried to constant weight in a water-oven at 98°-99°C, weighed and then incinerated. The weight of the dried residue minus the weight of the ash gave the weight of the fiber.

Crude protein.—The total nitrogen was determined by the Kjeldahl-Gunning-Arnold method. It was then multiplied by the factor 6.25 to obtain the amount of protein.

Carbohydrates.—The sum of the percentages of the individual carbohydrates determined, with the exception of those of cellulose, is considered as the percentage of carbohydrates.

THE IDENTIFICATION OF THE CARBOHYDRATES

There are so far no satisfactory methods to identify all the carbohydrates in unknown mixtures. Browne (17) and Hawk (18), however, give several tests that are claimed to fully identify certain carbohydrates. The following are the descriptions of the tests which gave positive results with copra meal:

Starch.—The presence of starch was established by the iodine test. The formation of blue coloration (iodide of starch) was confirmed by microscopic examination.

Sucrose.—Oil free samples were extracted with water and the extracts treated with Fehling's solution before and after inversion with hydrochloric acid. A marked increase in the percentage of invert sugar after inversion was noted in each case. This was attributed to the presence of sucrose in the sample.[3]

Glucose.—In detecting the presence of glucose the saccharic acid test (17) was employed. A small portion of oil-free material was treated with nitric acid (sp. gr. 1.15) and evaporated on a water-bath. After treatment of the resulting syrup first with powdered potassium carbonate and then with glacial acetic acid the mixture was allowed to stand overnight. Shining rhombic crystals with all the characteristics of acid potassium saccharate were formed, showing the presence of glucose.

Fructose.—Pinoff's and Pieraert's methods (17) for detecting the presence of fructose were used, and both gave positive results. In Pinoff's method, a solution of the sample was treated with a reagent made by mixing 10 cubic centimeters of a 4 per cent ammonium molybdate solution and 10 cubic centimeters of water containing 0.2 cubic centimeters of glacial acetic acid. On heating, a bright blue coloration appeared. Solutions of other sugars are said to remain colorless under these conditions.

In the Pieraert's method, a reagent was prepared by dissolving 12 grams of glycocoll in water; 6 grams of copper hydroxide was then added gradually. The hot solution was cooled to 60° C, 50 grams of potassium carbonate were then added and the mixture was made up to one liter. The solution of the material to be tested was clarified with a solution of lead acetate, deleaded with sodium sulphate and then treated with the reagent. On heating to 30° C reduction took place after about half an hour. Only fructose is said to show reduction by this treatment.

[3] Other polysaccharides might be indicated by this test. The presence of sucrose was confirmed by comparing the polarization of the solution before and after inversion.

Galactose.—In testing for the presence of galactose by the mucic acid test, lactose was assumed to be absent since lactose also forms mucic acid on oxidation with nitric acid (17). About 100 cubic centimeters of a water-extract of oil-free samples were treated with 20 cubic centimeters of concentrated nitric acid (sp. gr. 1.4) and the mixture evaporated in a shallow glass vessel on a water-bath to a volume of about 20 cubic centimeters. After standing overnight a fine white precipitate of mucic acid formed.

Galactan.—A dry sample free from oil was extracted with cold water until free from sugars. The residue was then treated with nitric acid (sp. gr. 1.4) and evaporated almost to dryness. Ammonium carbonate was added in order to dissolve any mucic acid which might have formed, converting it into the soluble ammonium mucate. The mixture was filtered and the filtrate evaporated and then treated with nitric acid. A white precipitate of mucic acid which showed the presence of galactan formed.

Pentoses.—The furfural reaction was used as the qualitative test for pentoses (17). The pentoses were converted into furfural by distilling the material with hydrochloric acid of specific gravity 1.06. The presence of furfural in the distillate was tested by "aniline acetate paper". This was further confirmed by treating the distillate with a solution of phloroglucine in hydrochloric acid, producing a black precipitate of furfural phloroglucide. Hexose sugars and their condensation products, such as starch, cellulose, sucrose, etc., also form small amounts of furfural with hydrochloric acid but the yield is said to be too small to interfere with the test (17).

Pentosans.—Oil-free samples were extracted with cold water until free from pentoses and other sugars. The residue was then treated in exactly the same manner as for the pentoses. The tests gave positive results.

Dextrins.—In the evaporation of the alcohol extract of copra meal to be used in the quantitative determination of sugars it was observed that a white flocculent precipitate was formed in all cases. Since dextrin is dissolved by water and precipitated in hot alcoholic solution the writer suspected that dextrin might be present in the material. Qualitative tests for dextrin were therefore carefully run as follows: Oil-free samples were extracted with cold water and the extract evaporated to a small volume on a water-bath and treated with hot 95 per cent alcohol. The precipitate which formed was collected in a filter and washed with hot alcohol. It was then re-dissolved in hot water, re-precipitated with hot alcohol and again washed several times with hot alcohol. The precipitate which was then free from sugars was finally dissolved in hot water, hydrolysed with hydrochloric acid and then treated with Ost's solution. The decided formation of red cuprous oxide precipitate showed the presence of sugars which must have been formed by the hydrolysis of dextrins.

ESTIMATION OF THE CARBOHYDRATES

Actual determinations of the percentages of the different carbohydrates which were confirmed to be present by the qualitative tests were run, with the exception of glucose and fructose, the percentages of which were calculated from optical and chemical data. The following are descriptions of the methods employed in the analysis. They were taken largely, with few modifications, from the Official and Tentative Methods of Analysis published by the Association of Official Agricultural Chemists (15).

Extraction.—Ten grams of moisture and fat-free material were boiled on a water-bath with 150 cubic centimeters of 50 per cent alcohol solution for two hours in a flask provided with a reflux condenser. Great care was taken not to boil the mixture for over two hours for it was shown (19) that by so doing the starch and the disaccharides are hydrolysed. The extract was then filtered off and the residue washed with 50 per cent alcohol till it was free from sugars. The filtrate was made up to exactly one liter and aliquot portions were used for the determinations of sucrose and total reducing sugars. In the estimation of other sugars cold water extraction was used as will be seen later.

Sucrose.—Sucrose in the alcoholic extract prepared as above was determined by the double polarization (Clerget's) method. Inversion was accomplished at ordinary temperatures using hydrochloric acid.

Total reducing sugars.—Fehling's solution is most commonly employed in the determination of reducing sugars. It is, however, claimed that Ost's method is a far better and a more accurate one (20) since Ost's solution attacks sucrose less and is more sensitive than Fehling's solution. Bertrand's method of determining reduced copper is also said (20) to yield very reliable results besides being much less tedious than any of the other methods. For these reasons Ost's solution and Bertrand's method as modified by Van der Linden (21) were employed in these analyses. The reducing sugars were calculated as invert sugar, using Ost's table (20). The figures obtained were then reduced to glucose by dividing them by the factor 0.963, the reducing ratio of invert sugar to glucose.

Galactose.—It was desired to determine the percentages of galactose and galactan separately. As is well known, galactose is dissolved by cold water while galactan remains unaffected. Oil and moisture-free samples were therefore extracted with cold water until free from sugars and the extract analyzed for galactose as follows: A portion of the extract was treated with nitric acid of specific gravity 1.16, and the mixture evaporated almost to dryness on a water-bath. The crystalline precipitate of mucic acid which formed after standing overnight was dissolved by ammonium carbonate solution and then re-precipitated with nitric acid. The precipitate was finally collected in a tared filter and the amount determined gravimetrically. The weight of mucic acid was multiplied by the factor 1.3 to obtain the weight of galactose.

Galactan.—The residue left after the extraction of the sugars with cold water contained all the galactan. It was accordingly treated in exactly the same way as for galactose except that after dissolving the mucic acid with ammonium carbonate solution the mixture was freed from the insoluble residues by filtration before the mucic acid was reprecipitated. By this treatment the galactan had been hydrolysed by the acid into galactose which was then oxidised forming mucic acid. The weight of the latter was multiplied by 1.3×0.9 to obtain the percentage of galactan.

Pentoses.—Like galactose the pentoses can be separated from their condensation products, the pentosans, by cold water extraction. An extract similar to that used in the determination of galactose was therefore used for pentoses. The method recommended by the Association of Official Agricultural Chemists (15) was employed. The pentoses were converted into furfural by distilling the material with 12 per cent hydrochloric acid. The furfural was precipitated

as furfural phloroglucide. The precipitate was collected in a tared filter and determined gravimetrically. The corresponding weight of pentoses, calculated as xylose was obtained from Kröber's table (15).

Pentosans.—The residue left from the water extraction contained all the pentosans. It was treated in exactly the same manner as the pentoses. The pentosans were calculated from the weight of the phloroglucide precipitate obtained, using Kröber's table.

Glucose and fructose.—Having determined the percentages of sucrose, galactose, xylose, and the total reducing sugars, and the saccharimetric reading of sucrose normal weight, glucose and fructose were calculated by the following formulae given by Browne (17):

$$1.23gl+0.793g—1.356f+0.283x+S=P^4$$
$$0.898gl+g+0.915f+0.983x=R$$

in which

g = per cent glucose
f = " " fructose
gl = " " galactose
x = " " xylose
S = " " sucrose
R = " " total reducing sugars as glucose
P = saccharimetric reading of sucrose, normal weight
1.23 = polarizing ratio of galactose to sucrose
0.793 = " " " " glucose " "
1.356 = " " " " fructose " "
0.283 = " " " " xylose " "
0.898 = reducing ratio of galactose to glucose
0.915 = " " " " fructose " "
0.983 = " " " " xylose " "

Starch.—Starch in the sample was determined as follows: About 2 grams of moisture and oil-free material were stirred in a beaker with cold water for one hour. The mixture was then transferred into a filter and washed with cold water until free from soluble sugars or until the filtrate gave no positive test with alpha-naphthol (17). The residue was boiled with water on a water-bath for thirty minutes to gelatinize the starch. It was then subjected to the action of taka-diastase for three to four days at ordinary temperatures. A little toluene was added to prevent fermentation. At the end of this time the diastase was destroyed by boiling and the residue filtered and washed. The filtrate was diluted to a known volume. Aliquot portions were taken, hydrolysed with hydrochloric acid and then analyzed for sugars with Ost's solution. The yield of glucose was multiplied by the factor 0.9 to obtain starch.

Dextrin.—The determination for dextrin was based on the fact that it is soluble in water and precipitates in hot alcoholic solution. Moisture and oil-free samples were shaken and washed with cold water until free from sugars. The resulting extract was evaporated to a small volume on a water-bath and then treated with hot 95 per cent alcohol. The precipitate which formed was collected

[4] To simplify calculations, since these are only approximate anyway, raffinose was included in the figures for sucrose used in this formula, which figures were calculated directly from the results of the Clerget's determinations, as if raffinose were absent. These figures are naturally higher than those given in Table II after deducting raffinose.

and thoroughly washed with hot alcohol. It was then re-dissolved with hot water, re-precipitated with hot alcohol, collected and again thoroughly washed with more hot alcohol. The dextrin which was then free from sugars was finally dissolved with hot water, hydrolysed by boiling with hydrochloric acid for two hours and analyzed for sugars with Ost's solution in the ordinary way. The yield of glucose was multiplied by the factor 0.9 to obtain dextrin.

Cellulose.—In the determination of crude fiber already described, the 1.25 per cent acid and alkali solutions were supposed to dissolve all the lower forms of carbohydrates, the sugars, starch, dextrin, pentosans, galactan, etc., leaving the more resistant forms such as the cellulose, lignin, cutin, and others. It was thought that some hemicelluloses were partly affected by this treatment. In order to verify this, the residue from the acid and alkali digestion was analyzed both for galactan and for pentosans. As is well known the hemicelluloses may yield either hexosans or pentosans on treatment with strong acids. The results showed practically no hexosan and that the yield of pentosans was so small as to be entirely negligible. These showed that the hemicelluloses, if any was present, had apparently all been dissolved by the 1.25 per cent alkali and acid treatment and that it may not be far from correct, therefore, to suppose that the crude fiber obtained was practically all cellulose. In this particular experiment the percentages of crude fiber obtained were considered the percentages of cellulose.

RESULTS OF ANALYSES AND DISCUSSION

PROXIMATE ANALYSIS

Table I gives the results of the analysis of fourteen samples of the copra meal studied, calculated both in terms of the air-dry and oven-dried material.

A comparison of the above data with those of previous analyses (6) of the material shows that the sample studied did not differ very materially from the others of its kind and that it fairly represented the expeller product. By close examination of Table I it will be seen that while the results obtained for the fourteen samples do not exactly agree, they nevertheless come close to the average of reported analyses made elsewhere.

The percentages in terms of air-dry material of the different constituents in the fourteen samples ranged as follows: moisture 10.24–11.94; ash 5.14–5.69; protein 20.05–21.53; oil 13.61–14.66; water-soluble free organic acids calculated as oleic acid 6.54–7.92; crude fiber 13.34–14.53; and carbohydrates 24.11–25.98. Calculated in terms of the oven-dried samples the percentage composition ranged as follows: ash 5.67–6.43; protein 22.64–24.38; oil 15.37–16.44; water-soluble free organic acids calculated as oleic acid 7.46–8.95; crude fiber 14.97–16.37; and carbohydrates 27.19–29.18. It should be noted that the percentages of oil were obtained by subtracting the percentages of water-soluble free organic acids calculated as oleic acid from the percentages of the total ether extract, since it was found that the free acids were also extracted by the ether. These percentages of oil probably include the water-insoluble but ether soluble organic acids.

TABLE I.—*The composition of copra meal.*

(Figures under "A" express the percentages of the different constituents in terms of air-dry sample; figures under "B" express percentages in terms of oven-dried sample.)

Number of sample.	Moisture.	Ash.		Protein.		Oil.		Water-soluble fatty acids.		Crude fiber.		Other carbohydrates.		Undetermined.	
	A	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1	11.34	5.69	6.43	20.42	23.03	14.28	16.10	7.33	8.27	13.54	15.27	24.11	27.19	3.29	3.71
2	10.86	5.44	6.09	20.93	23.48	14.66	16.44	7.14	8.01	13.48	15.12	24.72	27.73	2.77	3.13
3	10.93	5.53	6.19	20.77	23.32	14.39	16.16	6.94	7.79	13.34	14.97	25.49	28.62	2.61	2.95
4	11.26	5.20	5.86	20.43	23.02	14.61	16.41	7.14	8.04	14.53	16.37	24.74	27.88	2.09	2.42
5	11.94	5.16	5.86	21.48	24.38	13.91	15.79	6.94	7.88	13.82	15.69	24.74	28.10	2.01	2.30
6	11.47	5.14	5.81	21.53	24.32	14.18	16.02	6.74	7.61	13.50	15.25	24.82	28.02	2.62	2.97
7	12.00	5.26	5.98	20.15	22.89	14.17	16.11	7.14	8.11	13.99	15.90	24.75	28.13	2.54	2.88
8	11.66	5.32	6.02	20.58	23.30	14.00	15.82	6.54	7.40	14.03	15.77	24.94	28.23	2.93	3.46
9	10.24	5.19	5.67	21.52	24.02	14.16	15.78	7.14	7.95	14.16	15.78	25.26	28.14	2.33	2.66
10	10.37	5.62	6.27	21.41	23.88	14.05	15.68	6.94	7.74	13.86	15.46	25.74	28.72	2.01	2.25
11	10.98	5.44	6.11	21.53	24.18	14.12	15.64	6.94	7.79	13.79	15.49	24.47	27.49	2.73	3.30
12	11.47	5.53	6.24	20.05	22.64	13.61	15.37	7.92	8.95	13.92	15.72	25.98	29.18	1.52	1.90
13	11.80	5.39	6.11	20.97	23.77	14.03	15.90	6.94	7.87	13.86	15.71	24.26	27.51	2.75	3.13
14	10.34	5.52	6.15	21.46	23.93	13.94	15.55	7.14	7.96	13.64	15.21	25.62	28.57	2.34	2.63
Average	11.19	5.39	6.06	20.94	23.58	14.13	15.91	7.07	7.96	13.82	15.55	24.90	28.17	2.50	2.83

It will be seen that almost one half of the total constituents of the material studied were carbohydrates. The figures for total carbohydrates were obtained by taking the sum of the percentages of the individual carbohydrates determined. These evidently may or may not include any of the rarer and less important carbohydrates which might also be present but which have not been identified and determined. The average percentage of undetermined constituents was 2.50 in terms of the air-dry sample and 2.83 in terms of the oven-dried material. The nature of these undetermined constituents has not been studied.

THE NATURE OF THE CARBOHYDRATES

Eight different carbohydrates were definitely confirmed to be present in copra meal, namely, sucrose, glucose, fructose, galactose, starch, dextrin, galactan, and cellulose. Sucrose was identified by the inversion-reduction test, glucose by the saccharic acid test, fructose by the Pinoff and also by the Pieraert test, galactose and galactan by the mucic acid test and starch by the microscopic iodine test. Dextrin was isolated by alcohol precipitation. In addition to these carbohydrates, pentoses and pentosans were also identified by the furfural test and the presence of raffinose is suspected because of the difference in the calculated percentage of sucrose and direct polarization. It was not, however, determined what particular pentoses and pentosans were present. At least, therefore, 10 different carbohydrates were present in the copra meal studied. Table II gives the relative percentages of these different carbohydrates both in terms of the oven-dried material and in terms of total carbohydrates.

As will be seen in Table II the average percentage of sucrose in the material analyzed was 14.33 in terms of the oven-dried sample. This is lower than the results obtained by Van Kampen (13) which was 17.5 per cent, but the difference may be due to the fact that raffinose was not accounted for in Van Kampen's analyses.

The following were the average percentages of the other carbohydrates in terms of the oven-dried copra meal: galactose 2.42; pentoses 2.40; glucose 1.19; fructose 1.20; starch 0.87; dextrin 0.58; galactan 0.50; pentosans 2.22; and cellulose 15.55. For a more complete idea of the nature of these carbohydrates their percentages were calculated in terms of total carbohydrates in the sample. These are also shown in Table II. Excluding crude fiber, sucrose was the carbohydrate present in greatest amount, being about 32.82 per cent of the total carbohydrates. The average percentages of the other carbohydrates in terms of the total carbohydrates were as follows; cellulose 35.63; galactose 5.54; pentoses calculated as xylose 5.49; pentosans calculated as xylan 5.09; fructose 2.75; glucose 2.72; starch 1.98; dextrin 1.29; and galactan 1.15. Of the total carbohydrates present, 54.86 per cent were sugars while 45.14 per cent were polysaccharides.

It will be seen that galactose and pentoses were the reducing sugars present in greatest amounts. It is striking to note that they were present in almost identical quantities, the average per cent in terms of total carbohydrates of galactose being 5.54 and that of pentoses 5.49. As is true in most other plant products glucose and fructose were present in almost the same amount, being about 2.72 per cent and 2.75 per cent of the total carbohydrates, respectively. They were probably in the form of invert sugar derived by the hydrolysis of sucrose. It is also interesting to note that the sum of the percentages of glucose and fructose pretty nearly equalled either that of galactose or that of the pentoses. It may be stated then that the reducing sugars in the samples were composed of about equal amounts of galactose, pentoses and invert sugar (glucose and fructose).

About 35.63 per cent of all the carbohydrates was crude fiber. All the other polysaccharides amounted to 9.51 per cent (45.14–35.63) and were composed of starch, dextrin, galactan, and pentosans. The average per cent in terms of total carbohydrates of pentosans calculated as xylan was 5.09. Of all the carbohydrates identified, galactan was present in least amount, being only about 1.15 per cent of the total carbohydrates present and about 0.50 per cent of the oven-dried material. About 1.98 per cent of the total carbohydrates was starch and 1.29 per cent was dextrin. As is well known, starch is converted into dextrin by the action of heat and also by dilute acids. Leoncini (22) claimed that the presence of dextrin in chestnut meal was due to too high a temperature during the roasting of the nut. The presence of free organic acids in copra meal and the excessive heating during the process of desiccation of copra may be the causes of the formation of dextrin from starch and invert sugar from sucrose in the meal.

SUMMARY

1. Copra meal (expeller product) was analyzed for proximate composition and the nature of the carbohydrates present determined. The methods of analysis employed in the determination of the proximate composition and in the identification and estimation of the carbohydrates are described. The results are tabulated.

2. The average percentage composition of the material studied was as follows:

In air-dry sample.—Moisture 11.19; ash 5.39; protein 20.94; oil 14.13; water-soluble free organic acids calculated as oleic acid 7.07; crude fiber 13.82; carbohydrates 24.90; undetermined 2.50.

In oven-dried sample.—Ash 6.06; protein 23.58; oil 15.91; water-soluble free organic acids calculated as oleic acid 7.96; crude fiber 15.55; carbohydrates 28.17; undetermined 2.83.

3. The following carbohydrates have been identified in copra meal: sucrose, raffinose, galactose, pentoses, fructose, glucose, cellulose, pentosans, starch, dextrin, and galactan. Table III shows the nature of these carbohydrates in the material studied.

TABLE II.—*The nature of the carbohydrates in copra meal.*

[Figures under "A" express the percentages of the different carbohydrates in terms of oven-dried copra meal; figures under "B" express the percentages in terms of total carbohydrates.

Number of sample.	Total reducing sugars as glucose.		Sucrose by polarization.		Raffinose calculated.		Galactose.		Pentoses calculated as xylose.		Glucose calculated.		Fructose calculated.		Starch.		Dextrin.		Galactan.		Pentosans calculated as xylan.		Crude fiber as cellulose.		Total sugars.		Total polysaccharides		Total carbohydrates.
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1	6.61	15.57	14.17	33.37	2.23	5.25	2.42	5 70	2.13	5.02	1.30	3.06	1 14	2.69	0.71	1.67	0 50	1.18	0 49	1.15	2 10	4.95	15.27	35 96	23 39	55 09	19.07	44 91	42.46
2	6.61	15.43	14.25	33.25	2.46	5.74	2.42	5.65	2.25	5.25	1.08	2.52	1.25	2.92	0.95	2.22	0 53	1.24	0.44	1.03	2 10	4.90	15 12	35 28	23.71	55 33	19.14	44 67	42.85
3	6.71	15.39	14.77	33.88	2.61	5.99	2.83	6.49	2.61	5.99	0.86	1.97	1.08	2.48	0.86	1.98	0 54	1.24	0 41	0.94	2 05	4 70	14.97	34 34	24 76	56 80	18 83	43 20	43.59
4	7.14	16.14	14.18	32.05	2.23	5.04	2.56	5.78	2.45	5.54	1.27	2.87	1.27	2.87	0.90	2.03	0 53	1.19	0 44	0 99	2.05	4.65	16.37	36 99	23.96	54 17	20 29	46 08	44.25
5	6.64	15.16	14.51	33.13	2.53	5 78	2.31	5.28	2.46	5.62	1.00	2.28	1.27	2.90	0.87	1.99	0 59	1.35	0.50	1 14	2.06	4 70	15.09	35 83	24 08	54 99	19 71	45 01	43 79
6	6.87	15.88	14.31	33.07	2.48	5.73	2.39	5.52	2.63	6.08	1.01	2.33	1.24	2.87	0.84	1.94	0.59	1 37	0 48	1.11	2 05	4.74	15 25	35 24	24 06	55 60	19 21	44 40	43.27
7	6.87	15.60	13.99	31.77	2.38	5.41	2.45	5.56	2.50	5.68	1.26	2.86	1.14	2.59	0.99	2.25	0 51	1.16	0 57	1.29	2 34	5 32	15.90	36 11	23 72	53 87	20 31	46 13	44 03
8	6.47	14.70	14.75	33.52	2.40	5.46	2.43	5.52	2.12	4.82	1 16	2.64	1.15	2.61	0.90	2 05	0 52	1 18	0.52	1 18	2 28	5.18	15.77	35 84	24.01	54 57	19 99	45 43	44 00
9	6.85	15.60	13.22	30.10	2.58	5.87	2.56	5.83	2.09	4 76	1.44	3.28	1.14	2.60	0.90	2.05	0 60	1.36	0.43	0 98	3 18	7 24	15.78	35 93	23 03	52 44	20 89	47 56	43 92
10	6.91	15.64	14.56	32.96	2.34	5.30	2.49	5.64	2.46	5.57	1.52	3.44	1.22	2.76	0.80	1.81	0 54	1.22	0.46	1.04	2 33	5 27	15.46	34 99	24.59	55 66	19 59	44 34	44 18
11	6.65	15.50	14.15	32.98	2.22	5.17	2.26	5 27	2 33	5 43	1.25	2.91	1.15	2.68	0.82	1.91	0 64	1 49	0.60	1 40	2 00	4 66	15 49	36 10	23 36	54 44	19 55	45 56	42 91
12	6.96	15.50	14.94	33.27	2.46	5.48	2.16	4.81	2.32	5 17	1.43	3 19	1.43	3.18	0.90	2.00	0.48	1.07	0.60	1.34	2 46	5.48	15.72	35 01	24.74	55 10	20 16	44 90	44 90
13	6.50	15.04	14.12	32.67	2.42	5.60	2.32	5.37	2.54	5 88	1.00	2.31	1.02	2 36	0.83	1.92	0 65	1.50	0.54	1.25	2 07	4 79	15 71	36 35	23.42	54 19	19 80	44.38	45.22
14	6.90	15.76	14.64	33.44	2.57	5.87	2.28	5.20	2.68	6.12	1.10	2.51	1.33	3 04	0.87	1.99	0.62	1.42	0.50	1 14	1 98	4 52	15 21	34 74	24 60	56 19	19 18	43 81	43 78
Average	6,76	15.49	14.33	32.82	2.42	5.54	2.42	5.54	2.40	5 49	1.19	2.72	1.20	2 75	0.87	1.98	0.58	1.29	0.50	1.15	2.22	5.09	15.55	35.63	23.96	54.86	19 72	45.14	43 68

TABLE III.—*The nature of the carbohydrates in copra meal (Summary).*

CARBOHYDRATES.	In terms of oven-dried sample.	In terms of total carbohydrates.	In terms of total sugar.	In terms of total polysaccharides.
Sugars:	average *per cent*	average *per cent*	average *per cent*	average *per cent*
Sucrose	14.33	32.82	59.82	
Raffinose	2.42	5.54	10.10	
Galactose	2.42	5.54	10.10	
Pentoses (as xylose)	2.40	5.49	10.01	
Fructose	1.20	2.75	5.01	
Glucose	1.19	2.72	4.96	
Polysaccharides:				
Cellulose	15.55	35.63		78.93
Pentosans (as xylan)	2.22	5.09		11.28
Starch	0.87	1.98		4.39
Dextrin	0.58	1.29		2.85
Galactan	0.50	1.15		2.55
TOTAL	43.68	100.00	100.00	100.00

ACKNOWLEDGEMENT

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INVESTIGATION OF CONDITIONS AFFECTING THE QUANTITATIVE DETERMINATION OF REDUCING SUGARS BY FEHLING SOLUTION AND THE ELIMINATION OF CERTAIN ERRORS INVOLVED IN THE CURRENT METHODS.[1]

By F. A. Quisumbing and A. W. Thomas

"1. From this investigation, it is concluded that the current methods for the determination of reducing sugars are not satisfactory, because conditions for temperature control have not been well established.

"2. The amount of reduction of Fehling solution by dextrose has been measured at temperatures from 60° to 110° C., and time of heating from 10 minutes to 2 hours and conditions at 80° C. for 30 minutes have been found best for reduction. The degree of accuracy in determination by this method is approximately ±0.12% when the temperature is maintained at 80° C. ±0.1°. If the heating power is regulated by a set of burners, the error introduced by fluctuation in temperature is approximately ±0.3% for ±1° and ±0.65% for ±2° around 80° C.

"3. Auto-reduction of Fehling solution at different temperatures and lengths of time of heating has been measured and found that the error inherent to these factors can be eliminated.

"4. Surface oxidation and reduction have been studied and found that the amount of cuprous oxide lost due to surface oxidation is proportional to the area of the liquid exposed to the air, and the error inherent thereto is obviated by the use of watch glass. Reduction is proportional to the lateral area of the glass; that is, the higher the column of liquid exposed to the glass surface, the more cuprous oxide is precipitated.

"5. A thorough study of Fehling's reagent has been made and shown how the nature and amount of alkali in Fehling solution influence reduction and physical character of cuprous oxide form. Sodium hydroxide in Fehling solution gives a more satisfactory precipitation than when potassium hydroxide or the carbonates are used. "1.6 normal Fehling solution" has been found best for the oxidation of the sugars. The concentration of Cu^+ and OH^- ions influence the rate and amount of oxidation of sugars. The amount of copper reduced increases with increasing concentrations of Cu^+ and OH^- ions up to a certain point, where oxidation is at its maximum, and from that point, further increase in Cu^+ and OH^- tends to decrease reduction. Increasing the concentration of Rochelle salt beyond that called for by Soxhlet-Fehling solution formula shows no material effect. A modified Fehling solution has been prepared that gives no "blank" reduction.

"6. A comparative study of the reducing action of sucrose on Fehling solution and reducing sugars has been made and found that the reducing action

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[1] A contribution from the Chemical Laboratories of Columbia University, New York City. The abstract here given is from the **Louisiana Planter and Sugar Manufacturer 66**:363. 1921. For purposes of reference the table for calculating dextrose, levulose, invert sugar, lactose and maltose is added to the abstract. The entire paper was read at the semi-annual meeting of the Sugar Chemists' and Technologists' Section of the American Chemical Society at Rochester, New York, April 27-29, 1921.

of sucrose can be eliminated. The presence of as much as 400 milligrams of sucrose does not affect the accuracy of determinations of dextrose and invert sugar. In case of mixtures of sucrose and levulose, slight reduction due to sucrose is shown by 300 milligrams; sucrose and lactose, 200 milligrams; and sucrose and maltose, 100 milligrams. Maltose has a marked catalytic effect on the reducing action of sucrose. It is concluded, therefore, that reduction by sucrose is not entirely a matter of hydrolysis of its molecule, but is a direct function of the molecule itself.

"7. Measure accurately 25 cc. each of copper sulphate and alkaline tartrate solutions (prepared as described on page 26) into a 400 cc. Pyrex or Bohemian glass beaker, the diameter of which is approximately 9 cm. Add 50 cc. sugar solution, making a total volume of 100 cc. Cover the beaker containing the mixed solutions with a watch glass and submerge it in a water bath which is regulated at 80° C. After exactly 30 minutes digestion filter the cuprous oxide precipitate by suction through a mat of asbestos in a Gooch crucible. The precipitate is washed in the usual manner with warm water and the copper determined by one of the common methods. From the weight of copper or cuprous oxide obtained, find the corresponding weight of reducing sugar from the Table, or calculate it by means of the equations.

"Weights of the sugars to be taken for analysis:

"For dextrose, levulose and invert sugar, take 50 to 150 milligrams; for lactose and maltose, take 100 to 300 milligrams. These weights of the sugars will reduce about 100 to 350 milligrams of copper.

"In the presence of sucrose, the weight of sugar for analysis can be judged by a preliminary test of the sample, but in any case, if not more than 100 milligrams of sample be used, there will be no error due to sucrose.

"8. Reduction by dextrose, levulose, invert sugar, lactose and maltose of different concentrations has been made and a sugar table constructed from the calculated equations.

$$\begin{aligned}
\text{(Dextrose)} \quad & y = 0.474\,x + 0.000115\,x^2 \\
\text{(Levulose)} \quad & y = 0.526\,x + 0.000078\,x^2 \\
\text{(Invert Sugar)} \quad & y = 0.504\,x + 0.000087\,x^2 \\
\text{(Lactose)} \quad & y = 0.813\,x + 0.000003\,x^2 \\
\text{(Maltose)} \quad & y = 0.990\,x + 0.0000005\,x^2
\end{aligned}$$

Where y = milligrams of sugar and x = milligrams of copper."

The table on page 71 gives figures for calculating dextrose, levulose, invert sugar, lactose, and maltose.

DISCUSSION

"Several chemists in the discussion of this paper spoke of the excellent results which had been obtained at Columbia University with Stillman's new electrolytic method for the determination of copper. With reference to the precautions for preventing the reducing action of sucrose upon Fehling solution, C. A. Browne mentioned that what was most needed at present was a method for estimating accurately a few milligrams of reducing sugar in presence of five grams or more of sucrose."

Table for calculating dextrose, levulose, invert sugar, lactose, and maltose.

Copper (Cu).	Cuprous oxide (Cu_2O).	Dextrose (d-glucose).	Levulose (d-fructose).	Invert Sugar.	Lactose.		Maltose.	
					$C_{12}H_{22}O_{11}$.	$C_{12}H_{22}O_{11}$. H_2O.	$C_{12}H_{22}O_{11}$.	$C_{12}H_{22}O_{11}$. H_2O.
10	11.1	4.8	5.3	5.0	7.7	8.1	9.4	9.9
20	22.5	9.5	10.5	10.1	15.5	16.3	18.8	19.8
30	33.8	14.3	15.8	15.2	23.2	24.4	28.2	29.7
40	45.0	19.1	21.2	20.3	30.9	32.5	37.6	39.6
50	56.3	24.0	26.5	25.4	38.7	40.7	47.0	49.5
60	67.6	28.9	31.9	30.6	46.4	48.8	56.4	59.4
70	78.8	33.7	37.2	35.7	54.0	56.9	65.8	69.3
80	90.1	38.7	42.6	40.9	61.7	65.0	75.2	79.2
90	101.3	43.6	48.0	46.1	69.5	73.2	84.6	89.1
100	112.6	48.6	53.4	51.3	77.2	81.3	94.0	99.0
110	123.8	53.5	58.8	56.5	85.0	89.5	103.4	108.9
120	135.1	58.5	64.3	61.8	92.7	97.6	112.8	118.8
130	146.4	63.6	70.7	67.0	100.4	105.7	122.2	128.7
140	157.6	68.6	75.2	72.3	108.2	113.9	131.6	138.6
150	168.9	73.7	80.7	77.6	116.0	122.0	141.0	148.5
160	180.1	78.8	86.2	82.9	123.7	130.1	150.4	158.4
170	191.4	83.9	91.7	88.3	131.4	138.3	159.8	168.3
180	202.6	89.1	97.2	93.7	139.1	146.4	169.2	178.2
190	213.9	94.2	102.8	99.1	146.9	154.6	178.8	188.1
200	225.2	99.4	108.4	104.4	154.6	162.7	188.2	198.0
210	236.4	104.6	114.0	109.8	162 3	170.9	197.6	207.9
220	247.7	109.9	119.6	115.2	170.0	179.0	207.0	217.8
230	258.9	115.1	125.2	120.6	177.8	187.2	216.4	227.7
240	270.2	120.4	130.8	126.1	185.5	195.3	225.8	237.6
250	281.5	125.7	136.4	131.6	193.2	203.4	235.2	247.5
260	292.7	131.0	142.1	137.1	201.0	211.6	244.6	257.4
270	304.0	136.4	147.8	142.6	208.8	219.8	254.0	267.3
280	315.2	141.7	153.5	148.2	216.5	227.9	263.4	277.2
290	326.5	147.1	159.2	153.7	224.2	236.0	272.8	287.1
300	337.8	152.6	165.0	159.3	232.0	244.2	282.2	297.0
310	349.0	158.0	170.7	164.9	239.7	252.3	291.6	306.9
320	360.3	163.5	176.5	170.5	247.5	260.5	301.0	316.8
330	371.5	168.9	182.3	176.1	255.3	268.7	310.4	326.7
340	382.8	174.5	188.1	181.8	263.0	276.8	319.8	336.6
350	394.0	180.0	193.9	187.4	270.7	285.0	329.2	346.5
360	405.3	185.5	199.7	193.1	278.4	293.1	338.6	356.4
370	416.6	191.1	205.5	198.8	286.2	301.3	348.0	366.3
380	427.8	196.7	211.4	204.5	293.9	309.4	357.4	376.2
390	439.1	202.3	217.3	210.2	301.6	317.5	366.8	386.1
400	450.3	208.0	223.2	216.0	309.4	325.7	376.2	396.0
410	461.6	213.7	229.1	221.8	317.1	333.8	385.6	405.9
420	472.9	219.4	235.0	227.6	324.9	342.0	395.0	415.8
430	484.1	325.1	240.9	233.4	332.6	350.1	404.4	425.7
440	495.4	230.8	246.9	239.2	340.4	358.3	413.8	435.6
450	506.6	236.6	252.9	245.0	348.1	366.4	423.2	445.5
460	517.9	242.4	258.9	250.9	355.9	374.6	432.6	455.4
470	529.1	248.1	264.9	256.8	363.6	382.7	442.0	465.3
480	540.4	250.8	270.9	262.7	371.3	390.9	451.4	475.2

STARCH FROM CASSAVA[1]

By Manuel L. Roxas and Ramon V. Manio

Cassava as a famine food and as a cheap source of starch in the Philippines are the subjects of papers by Copeland (1) and Bacon (2). In these papers the history and some chemical and agronomical studies of this plant are given. A brief discussion of its industrial possibilities and a description of a simple machine for starch are also included. This was back in 1908. Subsequently, and at the suggestion of Doctor Copeland, who was then dean of the College of Agriculture, a larger and much improved machine, designed on the principle of the small one referred to above, but run by a motor, was made under the direction of Professor Cuzner, the College engineer. The present paper gives an account of a test made with this machine.

MATERIALS AND METHODS

The experiments presented in this paper were carried out by the junior author. The grinding machine for cassava consists essentially of a power-driven cylinder on which is mounted a cylindrical grater, the roots being fed on to the cylinder through a hopper on the top. The grater was made by driving the points of sharp nails through a sheet of galvanized iron. A stream of water plays on this cylinder so as to keep it washed free from grated material. After the material is grated, it falls on to an oscillating sieve which is set at a slight angle so that the fiber, which is left after the starch is washed out, falls off the lower end. The starch and water fall through into a trough which has a very slight pitch so that the current is slow, allowing the starch to settle as the water is drawn off.

Two tests were made, using roots from Madioca Basiarao[2] (College Number 3898), eleven months old. In these tests two men were used, one at the motor and one at the hopper. The motor was two-horse-power run by kerosene. The results are shown in Table I.

Table I.—*Results of two tests with the starch machine.*

Test No.	Wt. of roots used.	Air-dry starch obtained.	Per cent extraction.	Time required.
	kg.	*kg.*	*per cent*	*minutes*
1	24.95	5.8	23.3	24
2	148.00	36.24	24.2	162

CALCULATIONS OF THE PRODUCTION COST PER KILOGRAM OF CASSAVA STARCH

The average production cost per kilogram air-dry starch was estimated from these data and from the cost of land preparation to be as follows:

Capacity of the machine per hour with 2 laborers..... 55.2 kg. of roots.

[1] Abstract from a thesis presented by Ramón V. Manio for the degree of Bachelor of Science in the College of Agriculture, No. 123; Experiment Station contribution, No. 53.

[2] In a field test made at the College of Agriculture this variety gave 87 tons per hectare at the age of 11 months.

Expenses of the machine, including oil, fuel, interest, and 2 laborers at 12.5c.[3] an hour, etc	42.5 cts.
Cost per kg. of roots	.77 cts.
Estimated yield of roots per hectare	50 tons.
Operating cost at .77 cts. per kg. for 50 tons	₱385.00
Production cost of cassava roots	₱100.66[4]
Total cost per 50 tons roots	₱485.66
Yield of starch from 50 tons roots at 24% extraction	12 tons.
Cost per kg. starch produced	₱ .0405.

To the above cost, a charge estimated at 5 centavos a kilogram of starch should be added for over-head charges, i.e., for packing, shipping, depreciation on the implements used, interest on the money invested, advertisement, etc. This would bring the total cost to about 10 centavos per kilogram.

Figuring on the production cost of 10 centavos and a wholesale price of 20 centavos per kilogram or 10 centavos net gain per kilogram of starch, cassava, when raised for this product, would give the farmer a net return of ₱1200 per hectare. The wholesale price may be cut down to 15 centavos per kilogram and still leave a net profit of ₱600 per hectare which is considered a very good return. When this price is compared with the price of corn starch which is sold in pound packages at 35 centavos a package and gaw-gaw[5] at 40 centavos a kilogram, it still leaves a wide margin of profit for the cassava grower.

PREPARATION OF CASSAVA FLOUR

The preparation of flour consists simply of grinding the peeled roots without water and drying the product[6] in the sun or with the aid of artificial heat to a moisture content of about 15 per cent. In this method, cassava flour of about 74.06 per cent starch content will be obtained which can be sold to the manufacturers of glucose or denatured alcohol. The cost of production per kilogram of flour is less than that of starch as the weight obtained from a hectare will be much greater. Assuming an average yield of 50 tons of roots per hectare, the yield of air-dry flour would be 21.77 tons.

The cost of production of cassava flour from 50 tons of roots would be about the same as of starch, as the cost for the wash water is not included in the calculations. The cost per kilogram of flour would then be $\frac{485.66}{21.77} = 2.22$ cts.

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(1) Copeland, E. B. Manioc or cassava. The Philippine Agricultural Review **1**: 139-156. 1908.

(2) Bacon, R. F. Starch production in the Philippine Islands. Philippine Journal of Science **3A**: 93-96. 1908.

[3] This work was done in 1918. The cost of labor at the present time (Sept. 1921) is about 16.0c an hour. No attempt has been made to bring the figures to present rates since these calculations are good for comparative purposes only.

[4] This figure was obtained from the records of the Department of Agronomy.

[5] Gaw-gaw is cassava starch manufactured in Singapore and China and is widely sold in grocery stores throughout the Philippines.

[6] Fresh roots contain 37% of dry matter or moisture-free flour. Air-dry flour contains 15% water. 50 tons of roots yield $\frac{37 \times 50}{100}$ or 18.5 T. dry matter.

18.5 tons dry matter yield $\frac{100 \times 18.5}{85}$ or 21.77 T. air-dry flour.

INDUSTRIAL ALCOHOL FROM CASSAVA[1]

By Manuel L. Roxas and Ramon V. Manio

The possibilities of alcohol as a substitute for gasoline, now that the latter "bids fair to become higher and higher in price," are now engaging the minds of engineers. It will be a question of only a few years before alcohol will be the source of cheap power in towns and on farms. Cassava, because of its relatively high starch content and large yield per hectare, will be one of the logical cheap sources of alcohol. It was for this reason, mainly, that it was thought worth while to study the proper conditions for the hydrolysis of cassava starch and its fermentation into alcohol.

So far as the authors know no work has ever been published along this line.

The work presented in this paper had the following specific objects in view:

1. To study the best strain of yeast for cassava.
2. To determine the best practical conditions for the hydrolysis of the starch.
3. To find the length of time of fermentation.
4. To find out the effect of certain stimulants on the yield of alcohol.
5. To study the use of the Molhant process.
6. To determine the value of the residue.

Starch and flours described in a previous paper (see p. 73 this number) were used in all these experiments.

YEASTS USED IN FERMENTATION

Three yeast preparations were used in these experiments. One was from a pure culture of *Saccharomyces ellipsoideus*, originally obtained from a distillery in Java and kindly donated to us by Mr. K. B. Grae of the Bureau of Science; the second was from the San Miguel Brewery in Manila; and the third was from the Malolos distillery, Malolos, Bulacan.

The yeast from the Malolos distillery was used for fermenting either molasses alone, or a mixture of molasses and nipa toddy, tuba. That from San Miguel Brewery was used in making beer. These strains were propagated in agar slants, but without separating them in *pure culture*. The medium used contained in 100 cc. of solution two grams of agar, two grams of molasses, and 0.1 gram of Pasteur salt[2] and was sterilized in autoclave at 120° C. for 20 minutes.

The yeast was grown in these slants for three days immediately preceding use.

FERMENTING POWER OF YEASTS

To compare the fermenting power of these cultures of yeast, the following experiments were performed. The starch preparation for these and for subsequent experiments were prepared by taking 50 grams of air-dry starch or its equi-

[1] An abstract from a thesis presented by Ramón V. Manio for the degree of Bachelor of Science in the College of Agriculture, No. 123; Experiment Station contribution, No. 54.

[2] Pasteur salt mixture:

K_4PO_4	1.5 grams
$(NH_4)_3PO_4$	10.0 "
$MgSO_4$	0.2 "
Tartaric acid	2.0 "

valent of flour and hydrolysing under pressure at 120° C. for 2.5 hours with 55 cc. sulfuric acid solution containing 2 cc. of the concentrated acid (sp. gr. 1.84) per 100 cc. After hydrolysis, the solutions were partly neutralized with ammonium hydroxide leaving in the solution about one half of the free acid. The whole was then diluted to 500 cc. and inoculated with yeast, two samples being used for each strain. At the end of the second day, they were tested for alcohol. The results are given in Table I.

TABLE I.—*Comparison of fermentive power of pure and impure yeast.*

Brewery yeast.			Tuba yeast.			Bureau of Science yeast.		
Sample 1 Pct. of theoretical.	Sample 2 Pct. of theoretical.	Av.	Sample 1 Pct. of theoretical.	Sample 2 Pct. of theoretical.	Av.	Sample 1 Pct. of theoretical.	Sample 2 Pct. of theoretical.	Av.
56.8	56.8		57.56	52.4		81.5	79.0	
55.4	56.55	56.4	57.44	50.02	54.3	80.47	79.9	79.71

This experiment shows the advantage of using *Saccharomyces ellipsoideus* in the fermentation of cassava starch. In the experiments that follow, *Saccharomyces ellipsoideus* was used exclusively.

HYDROLYSIS

Starch ($C_6H_{10}O_5$) is not directly fermentable to alcohol by yeast; it has first to be converted to fermentable sugar by acid hydrolysis or diastase methods. This conversion of starch to sugar is termed saccharification. Theoretically, 162 parts of starch ($C_6H_{10}O_5$) would make 180 parts of fermentable sugar ($C_6H_{12}O_6$), while 180 of the latter would give 92 parts of absolute alcohol (C_2H_5OH), thus:

$$\underset{\text{(Starch)}}{C_6H_{10}O_5} + H_2O = \underset{\text{(Fermentable Sugar)}}{C_6H_{12}O_6}$$

$$162 + 18 = 180$$

$$\underset{\text{(Fermentable Sugar)}}{C_6H_{12}O_6} = \underset{\text{(Alcohol)}}{2C_2H_5OH} + 2CO_2$$

$$180 = 92 + 88$$

In other words, if the starch, after hydrolysis, were fermented by the yeast completely into alcohol, it should produce absolute alcohol to the amount of 56.78 per cent of the weight of the starch, a yield, however, which is never obtained in practice. The different yields of alcohol from different starch products obtained in alcohol factories in the United States are given in Table II (1)

TABLE II.—*Theoretical versus practical yield of alcohol from different agricultural products.*

Materials,	Theoretical yield of absolute alcohol.	Practical yield of absolute alcohol.	Per cent.
100 kg. Corn	36.82 kg.	29.82 kg.	80
100 kg. Rye	33.87 kg.	28.04 kg.	83
100 kg. Potatoes	11.35 kg.	8.74 kg.	77
100 kg. Sweet Potatoes	12.87 kg.	9.47 kg.	68
100 kg. Sugar Beets	12.4 kg.	7.85 kg.	64
Molasses per gallon	3.08 lbs.	2.81 lbs.	90

The theoretical yield from camoteng cahoy roots is calculated as follows: One hundred kilograms of fresh roots from plants 11 months old, on an average, contain 32 kilograms of starch and only traces of sugar. Then the theoretical yield would be $\frac{32 \times 56.78}{100} = 18.202$ kilograms of absolute alcohol.

One method of saccharifying starch is by heating with dilute acids under pressure. In practice, sulfuric acid, which is the cheapest acid, is used, and for economic reasons, it is desirable to saccharify with the smallest necessary amount of acid in a convenient length of time. When starch is hydrolysed, it is first converted by stages to dextrins, then to maltose and finally to glucose. When hydrolysis is incomplete as the result of using an insufficient amount of acid or the time of heating is not sufficiently long, the hydrolysate may contain all these hydrolysis products in greater or less proportion. Since neither dextrins nor maltose are directly fermentable by yeast, an incomplete hydrolysis would naturally cause a slower rate of fermentation resulting in a poor yield of alcohol. It is, therefore, of great importance in the fermentation of starch that the latter be completely hydrolysed.

The following experiments were performed to determine the lowest concentration of acid necessary to convert the starch completely into glucose in a convenient length of time of heating.

Duplicate two-gram samples of starch plus 25 cc. of the corresponding acid solutions of different concentrations were hydrolysed in an autoclave for 2.5 hours at 120° C. After hydrolysis, the hydrolysate was diluted to exactly 250 cc. and 10 cc. used for Soxhlet determinations. The results are given in Table III.

TABLE III.—*Rate of hydrolysis of cassava starch in different concentrations of acid.*

No. of mg. 1	No. of mg. 2	Av.	Conc. acid.	Cu_2O mg. 1	Cu_2O mg. 2	Av.	Glucose.	Av.
			per cent				*per cent*	
80.0	80.0	80.0	1cc. Conc.	154.0	153.8	154.15	78.40	78.9
80.0	80.0	80.0	2 " "	154.0	154.8	154.8	78.70	79.15
80.0	80.0	80.0	3 " "	152.7	150.8	151.75	78.0	78.60
80.0	80.0	80.0	4 " "	153.6	154.7	154.15	79.5	79.10

Table III indicates that 1 per cent acid hydrolyses the starch completely in 2.5 hours.

The proportion of acid solution and starch used in the above experiment was 2 to 25. In practice it would be desirable to use a smaller proportion of acid solution to cassava starch because of limited autoclave capacity. It was therefore, determined what amount of acid solution and length of time of heating were most favorable for alcoholic fermentation. In the following experiments the proportion of the amount of acid solution to the weight of starch used was about 1:1.

Eight duplicate 204-gram samples of air-dry starch were hydrolysed with 200 cc. of the acid solution using two concentrations of acid, viz., 1 cc. and 2 cc. concentrated sulfuric acid, (sp. gr. 1.84) for every 100 cc. of the solution and 4 different periods of time. After hydrolysis, the excess of acid was partially neutralized

with a solution of ammonium hydroxide of known strength leaving enough free acid to make the concentration 2 cc. acid to 1000 cc. of the final solution for fermentation. The samples were then diluted to one liter and inoculated with pure yeast (*Saccharomyces ellipsoideus*). At the end of 48 hours, 100 cc. of the liquid was drawn off from each and after neutralizing with sodium hydroxide, distilled for alcohol as given by Sherman (2). The results are shown in Table IV in which the yields of alcohol obtained are given in per cent of the theoretical yield from the starch, for each concentration and each period of time.

TABLE IV.—*Hydrolysation in different time and concentration.*

Number of hours.		1 hour.		1.5 hours.		2 hours.		2.5 hours.	
Strength of acid.		Pct. 1	Pct. 2	Pct. 1	Pct. 2	Pct. 1	Pct. 2	Pct. 1	Pct. 2
Alcohol per cent of the theoretical	A.	16.4	33.0	19.0	23.6	23.5	42.8	26.5	80.0
	B.	16.2	32.2	18.8	23.8	23.6	42.2	26.1	79.1
	Averages	16.3	32.6	18.9	23.7	23.6	42.5	26.3	79.5

The results of the above experiment show that hydrolysis with 2 cc. acid for every 100 cc. of solution for 2.5 hours gives the highest yield of alcohol. Higher concentration of acid and longer time of heating were not used because the concentrations of acids used already causes complete hydrolysis of the starch and the cause for the still low yield of alcohol obtained must be ascribed to reasons other than incomplete hydrolysis.

TIME OF FERMENTATION

The following experiments were performed to determine the proper time for distillation. Duplicate samples were fermented with *Saccharomyces ellipsoideus* and distilled after 24, 48, 72, and 96 hours. Acidity determinations were made by titrating 10 cc. of the fermenting liquid with N|10 NaOH, using phenolphthalein as indicator. The acidity is expressed in cc. N|10 alkali per 10 cc. of hydrolysate. The results are shown in Table V.

TABLE V.—*Rate of acid development of fermenting liquid with the use of Saccharomyces ellipsoideus.*

Time.	0 hour.	24 hours.	48 hours.	72 hours.	96 hours.
Per cent alcohol		37.5 37.6	50.0 49.9	84.0 83.4	80.0 80.0
Averages		37.6	49.9	83.7	80.0
Acidity in cc. N|10 alkali	10.2 10.2	13.0 12.9	14.0 14.5	20.0 19.1	27.9 27.7
Averages	10.2	12.9	14.5	19.5	27.8

The flasks in these experiments were left open after inoculating with the yeast to approximate conditions in practice. The initial acidity was determined before inoculation. A study of Table V will reveal the steady increase both in the per cent of alcohol and acid until the third day after which there was a decrease in the alcohol content, while the acidity increased, apparently at the expense of the former. The experiment also indicated that the fermented liquid should be distilled within the third day, if loss in alcohol is to be avoided.

In the above experiments a yield of from 80 to 84 per cent of the theoretical is obtained under the conditions given. It was suggested that this rather low yield of alcohol obtained might be due to the fact that the yeast used was not accustomed to the cassava preparation, and a higher yield would probably be obtained if the yeast were first accustomed to the latter. To test this point the yeast was alternately grown in cassava starch hydrolysate and on agar slants and the agar slant containing yeast from the third flask of cassava hydrolysate was used for fermentation in the usual way. The alcohol produced was determined by taking 100 cc. of the fermenting liquid and distilling as before. The results are given in Table VI.

TABLE VI.—*Fermentation with Saccharomyces ellipsoideus from agar slant and cassava hydrolysate.*

Theoretical yield of alcohol in 10 grams of air-dry starch.	Alcohol actually produced from 10 grams of starch.	Yield in per cent.
grams	*grams*	*grams*
	3.68	82.2
	3.43	76.8
	3.76	84.1
4.47	3.67	82.1
	3.55	79.4
	3.81	85.2
	3.83	85.7
Average		82.2

The experiment shows that there was no beneficial effect from preparing the yeast as given above. Other factors must be responsible for the low yield of alcohol. One of these may be the oxidation of the alcohol as it is formed by acid fermenters from the air that get into the container during fermentation.

The destruction of alcohol by these foreign organisms may be checked by the use of certain chemicals to which they are very susceptible, and which may at the same time stimulate the yeast to a greater activity, or by using yeast that has been accustomed to a high concentration of alcohol. It is known that yeast can be bred so as to be able to live in from 5 to 8 per cent of alcohol solution. This concentration would kill most any other micro-organism. The process involving this principle is known as the Molhant process.

EFFECT OF STIMULANTS ON THE PRODUCTION OF ALCOHOL BY YEAST

To determine the effect of certain stimulants on the fermentation of cassava preparations, the following experiments were performed. One hundred-gram samples of cassava flour and 50-gram samples of starch were hydrolysed as pre-

viously described and were fermented with pure culture of *Saccharomyces ellipsoideus*, in the presence of 0.1 gram of the different stimulants. After 36, and 60 hour periods, samples were drawn for the determination of alcohol. The results are given in Table VII.

TABLE VII.—*Effect of using different stimulants in fermenting cassava.*

STIMULANTS	Alcohol produced.							
	Starch.		Flour.		Highest yield.		Gain or loss over control.	
	36 hrs.	60 hrs.	36 hrs.	60 hrs.	Starch.	Flour.	Starch.	Flour.
None	73.7	66.9	79.0	80.7	73.7	80.7		
Pasteur Salt	60.8	85.8	89.9	78.7	85.8	89.9	12.1	9.2
$CaH_4(PO_4)_2$	77.8	81.2	85.1	83.9	81.2	85.1	7.5	4.4
Na_2F_2	62.5	81.6	80.0	82.7	81.6	82.7	7.9	2.0
$MgSO_4$	88.0	87.2	81.0	72.2	88.0	81.0	14.3	0.3
Na_2HPO_4	86.0	71.5	77.6	77.3	86.0	77.6	12.3	3.1

The experiment on the whole shows the good effect of the stimulants. The salt mixture (Pasteur) seems to retard the fermentation of air-dry starch, while it greatly stimulates the fermentation of flour. The $Ca(H_2PO_4)_2$, and $MgSO_4$ stimulates rapid fermentation in both air-dry starch and flour. While the Na_2HPO_4 promotes rapid fermentation in starch it seems to have no stimulating effect in the case of flour. Na_2F_2 seems to retard fermentation in both starch and flour. The last two columns of Table VII indicate the gain or loss in alcohol over the control. The figures show a greater increase on the yield of alcohol produced by the inorganic salts from the starch than from flour, due to the fact that the yield of alcohol in the preparations without the addition of stimulant is much higher from flour than from starch. The highest yield of alcohol was given by flour with the Pasteur salt mixture. The use of this salt mixture is not practicable in commercial fermentation on account of its cost.

THE MOLHANT PROCESS

Since low yield of alcohol in commercial fermentation is due mostly to loss caused by acetic fermentation by bacteria or wild yeasts, conditions that would inhibit the action of the latter, but would not affect the activity of the former, would favor high yield of alcohol. It is well known that yeast can be accustomed to conditions that ordinarily are unfavorable for its growth and would therefore stop the action of bacteria and wild yeast. Thus its resistance to a high concentration of alcohol can be increased by growing it in a gradually increasing concentration of molasses, until it is able to ferment relatively high concentration of sugar. A process, known as the Molhant process, has been developed taking advantage of this property. Brill and Thurlow (3) suggest the preparation of yeast to be used for inoculation in commercial fermentation according to this process.

The yeast from an agar slant culture was transferred to a 10 per cent (by volume) molasses solution previously sterilized at 100°C. for half an hour. From time to time, whenever fermentation was proceeding rapidly, more of the molasses solution was added increasing in this way the stock culture till the desired volume was obtained. Yeast prepared in this way was used in the following experiments.

The material used was air-dry flour from cassava. Samples of 500 grams each were hydrolysed with 490 cc. water and 10 cc. concentrated sulfuric acid, and after hydrolysis 25 cc. of ammonium hydroxide (sp. gr. 0.90), the whole diluted to 3.5 liters and 35 cc. of the inoculating solution prepared as above were added. To some of the preparations, magnesium sulfate or sodium acid phosphate was added. The percentage of starch content in the hydrolysate after dilution was determined by analysis by Soxhlet's method. Determinations for alcohol were made after 48, 72, and 96 hours. The averages of a number of determinations are given in per cent of the thoeretical yield in Table VIII.

TABLE VIII.—*Results with the use of yeast grown by the Molhant process, with and without the addition of certain stimulants.*

Sample No.	Treatment.	Theoretical yield of alkali from 100 cc (Calculated from result of analysis by Soxhlet Method.)	48-hr. Period		72-hr. period		96-hr. period		Highest yield.	Averages.
			Weight of alcohol.	Per cent of theoretical.	Weight of alcohol.	Per cent of theoretical.	Weight of alcohol.	Per cent of theoretical.		
		grams	*grams*	*per cent*	*grams*	*per cent*	*grams*	*per cent*		
I	None	5.2245	3.4876	66.74	4.5959	88.10	4.4568	85.22	88.10	
II		5.3178	3.6809	69.10	4.8412	90.90	4.5860	86.40	90.90	
III		5.4610	3.5957	65.84	4.7128	86.41	4.6727	85.59	86.41	86.53
IV		5.4865	3.9073	71.30	4.3919	80.14	4.4233	80.71	80.71	
V		5.3276	3.9305	73.74	4.7200	88.56	4.9364	92.98	92.98	
VI	$MgSO_4$	5.3276	4.1820	78.46	4.9045	92.00	4.6860	87.91	92.00	92.49
VII		5.0840	4.2319	83.30	4.6786	92.20	4.7035	88.24	92.20	
VIII	Na_2HPO_4	5.2780	4.2513	80.54	4.7539	90.00	4.6484	87.21	90.00	91.10
General average.										89.16

The results of these last experiments clearly indicate the advantage of the use of the Mohlant process of preparing yeast on a large scale for the fermentation of cassava flour. They also show that when using cassava flour, there is a fair increase in yield of alcohol resulting from the use of magnesium sulfate and sodium acid phosphate when the yeast is grown by Molhant process. Brill and Thurlow's work on discarded molasses has shown that their results on laboratory scale could be duplicated on large scale. The College does not have facilities such that fermentation of cassava on a large scale can be performed. From Brill and Thurlow's work and from the experiments above, the following is recommended for hydrolysis and fermentation of cassava flour on large scale.

Treat 100 kilograms of flour with 50 liters of acid solution containing 1 liter (1.84 kg.) of sulfuric acid, (sp. gr. 1.84,) and hydrolyse under pressure at 120°C for 2.5 hours. After hydrolysis, partially neutralize the liquid with 2 liters (1.79 kg.) ammonium hydroxide, (sp. gr. 0.9,) add 6 liters of inoculating solution, dilute to 600 liters and ferment. The fermented liquid should be distilled between the second and third days.

RESIDUE

Whenever the flour was used in hydrolysis or fermentation, as in the experiments discussed, there was left some unhydrolysed material. If not removed before fermentation, the fermented liquid could be filter-pressed and the resulting cake would probably have not inconsiderable value as fertilizer or as stock feed. Results of crude protein determination made on the residue after hydrolysis and before and after fermentation are shown in Table IX.

TABLE IX.—*Analysis for protein (Nx6.25) in the residue before and after fermentation.*

Before fermentation.			After fermentation.		
Sample 1.	Sample 2.	Average.	Sample 1.	Sample 2.	Average.
per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1.69	1.37	1.53	0.788	0.581	0.864

The experiment shows that the residue from hydrolysis contains higher percentage of protein than the residue after fermentation.

CALCULATION OF EXPENSES

Taking the average of alcohol obtained in the last experiments without the addition of salts at 86.5 per cent of the theoretical, the yield that could be expected from 100 kg. of air-dry flour would be $\frac{86.5\times56.79\times74.06}{100\times100}=36.38$ kg. of absolute alcohol or about one half of the weight of the starch contained in the air-dry flour.

The cost for the raw material per kilogram of alcohol from cassava is estimated as follows:

Cost of 100 kg. of flour at 2.22 centavos per kg.[3]	₱2.22
Cost of 1.84 kg. commercial sulfuric acid at 6.5 cts.	.12[4]
Cost of 1.79 kg. ammonium hydroxide 26° B. at 40 cts.	.72[4]
Total cost of raw material and chemicals for 100 kg.	₱3.05

or 8.43 centavos per kg. of absolute alcohol produced.

With the average yield of alcohol obtained in the experiments with the Molhant yeast with the addition of salt, the calculations of yield and expenses for raw material per 100 kilograms of air-dry flour would be as follows:

100 kilograms air-dry flour will produce $\frac{91.8\times56.79\times74.06}{100\times100}=38.6$ kilograms absolute alcohol.

Expenses:

Cost of 100 kg. of flour at 2.22 cts. per kg.	₱2.22
Cost of 1.84 kg. commercial sulfuric acid 5.5 cts. per kg.	0.12
Cost of 1.79 kg. ammonium hydroxide 26°B. 40 cts. per kg.	0.72
Cost of 300 gm. $MgSO_4$ or Na_2HPO_4 55 cts. per kg.	0.17
Total cost of raw material and chemicals per 100 kg. of flour	₱3.23

[3] See page 74 of this issue.

[4] This is the wholesale price of chemicals in New York on Febr. 15, 1919, plus 10 per cent.

Cost for raw material and chemicals per kilogram of alcohol produced $\frac{3.23}{3.86} = 8.45$.

These calculations show that there is no advantage in using magnesium sulfate or sodium acid phosphate since the cost of the additional amount of alcohol obtained is barely sufficient to counterbalance the cost of these chemicals.

The cost of molasses as raw material for alcohol per kilogram of this product is calculated from the figures published by Brill and Thurlow (3) as follows:

The average percentage of fermentable sugar (calculated as glucose) in 10 samples of molasses is 62.6. At an average yield of alcohol of 90 per cent of the theoretical, under Brill and Thurlow's conditions, 100 kilograms of this molasses would produce $\frac{90 \times 62.5 \times 51.11}{100 \times 100} = 28.8$ kilograms of absolute alcohol.

One hundred kilograms of molasses, (sp. gr. 1.443) are equal to 69.3 liters or 18.3 gallons, which at an average price of 10 centavos a gallon would cost ₱1.83. Brill and Thurlow advise the use of sulfuric acid and ammonium sulphate. One hundred kilograms of molasses according to them, were diluted to 440 liters and 880 grams sulfuric acid, and 180 grams of ammonium sulfate are to be added. The cost for these chemicals would be 5.3 centavos for acid and 5 centavos for ammonium sulphate bringing the total cost to ₱1.93 per 100 kilograms of molasses, or 7.1 centavos per kilogram of absolute alcohol produced.

According to the above calculations, the cost of cassava flour per kilogram of absolute alcohol produced would be 8.43 centavos as against 7.1 centavos for molasses. These calculations are based on cassava production of 50 tons of roots per hectare. The results show that cassava flour when made under the conditions of these experiments would cost about 1.33 centavos more per kilogram of alcohol produced than an equivalent amount of molasses. In commercial fermentation, however, with proper management and efficient machinery, the production cost of the flour will be lower than under College conditions. The production cost of the flour of cassava should thus be reduced to about 1.70 centavos per kilogram before it would become a cheaper source of alcohol than discard molasses when the latter sells at 10 centavos a gallon.

SUMMARY AND RECOMMENDATIONS

1. A study of the hydrolysis of cassava under different conditions and its fermentation to alcohol by different yeast preparations, with and without the use of stimulants, is given.

2. From the results of this study, the following is suggested for the hydrolysis of cassava flour for fermentation on a commercial scale:

For every 100 kilograms of cassava flour, use 50 liters of acid solution containing 1 liter sulfuric acid, (sp. gr. 1.84,) hydrolyse under pressure at 120°C. (15 lbs. per sq. in.) for 2.5 hours, neutralize it with 2 liters of ammonium hydroxide, (sp. gr. 0.9,) dilute it to 600 liters, and then add 6 liters of the yeast prepared by the Molhant process. The fermented liquid should be distilled after the second day but not later than the third day.

3. A comparison of the cost of cassava flour and molasses as raw material for alcohol manufacture is also given as follows:

(*a*) If the chemicals needed for the saccharification of cassava flour are taken into consideration, the total cost for raw material for production of one kilogram absolute alcohol from this plant is estimated at 8.43 centavos on a yield of 50 tons per hectare.

(*b*) Similar calculations made for molasses as the raw material for industrial alcohol give a cost of 7.1 centavos per kilogram of absolute alcohol for the raw material when the price of molasses is 10 centavos per gallon. Under the conditions given in this paper, cassava, therefore, would be more expensive as raw material for alcohol production than molasses.

(*c*) The production of cassava flour would have to be reduced to about 1.70 centavos per kilogram before it would be a cheaper source of alcohol than molasses. This could be accomplished by good management and the use of more efficient machinery.

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CHEMISTRY NOTES

Dr. Francisco A. Quisumbing returned from the United States on May 17, 1921, and immediately assumed his position as a member of the faculty of the College of Agriculture. Doctor Quisumbing studied at Columbia University as a Fellow of the University of the Philippines. His major was Pure Chemistry and his minor was Chemical Engineering.

Private correspondence from Francisco O. Santos states that he has completed the work for Ph. D. at Yale. He took his work under Professors Mendel and Osborne. He left Yale to take work in nutrition under Professors Sherman of Columbia and Lusk of Cornell. He was elected to active membership in the Yale Chapter of the Sigma Xi Society, March 15, 1921.

Mr. Cecilio Alincastre, M. S., 1920, pensionado from the College of Agriculture in Sugar Engineering, is at present in Massachusetts Institute of Technology taking Mechanical Engineering. He expects to complete his studies in Sugar Technology in the Audubon Sugar School in Louisiana.

Mrs. F. Navarro, instructor in chemistry, resigned, effective June 30, 1921. She expects to open a drug store in Manila.

Professor C. N. Laird of Canton Christian College donated six albino rats to the Department of Chemistry. One female has given birth to seven little rats. This is the first time that albino rats have been successfully reared in the Islands.

Mr. M. F. Koo of Canton Christian College is at the College of Agriculture taking some courses in Chemistry and Agronomy.

Mr. E. W. Kopke, formerly superintendent of the Canlubang Sugar Estate, has been appointed supervising chemist in the newly formed "Bank" centrals. He is professorial lecturer on sugar technology in the College of Agriculture.

The organic and analytical divisions of the Chemistry Department have moved into the new Chemistry Laboratory. The general chemistry class is still in the old Chemistry Building. The whole Chemistry Department will be in the new building before the end of the year.

Mr. J. T. Chioco, B. S., University of Illinois, and M. S., University of Louisiana, visited the College in June. Mr. Chioco has had some work as assistant sugar chemist in one of the sugar centrals in Cuba. He came to the Philippines *via* Europe, making the trip in an aeroplane from London to Paris. He expects to work in one of the centrals in Negros.

Mr. S. Asunción, B. Agr. 1912, a government pensionado, received the degree of Master of Science from the University of Louisiana. He specialized in Sugar Agronomy.

Mr. Segundo Labayan, B. Agr., 1915, M. S. University of Louisiana, is at present chief chemist of the Alto Cedro Sugar Co., Cuba. According to private letters to some of his friends in the College, he expects to visit the Philippines some time this year.

Mr. Felipe Adriano, B. Agr., 1919, and M. S. University of Wisconsin, is at present connected with the Canlubang Sugar Central. He is representing the Laguna-Batangas sugar planters.

The new sugar course in the College of Agriculture is attracting the attention of high school graduates. Records of the Secretary show that out of the 15 students enrolled in the course this year, 12 are high school graduates.

Mr. Ramon K. Habaluyas, B. Agr., 1919, is back in the College to complete the work for Master's degree. Last sugar season he was employed as representative of the Mindoro sugar planters to the Mindoro Sugar Co. Mr. Habaluyas' thesis subject is, "Comparative study of the different methods of sugar distribution."

Mr. Nemesio Catalan's application for admission to candidacy for the degree of Master of Science was approved by the Committee on Graduate Study, University Council. His thesis subject is "The ash content and the glucose ash ratio in the final molasses from a number of Philippine Centrals."

Mr. Tranquilino Ventura, B. Agr., 1919, formerly connected with the Oriental Products Co., is now assistant sugar chemist in Talisay Silay Central.

Mr. Alejandro Mangonon, B. Agr., 1920, visited the College last June. He is at present employed by the Tamaraw Plantation Co.

A new sugar mill, much larger and more completely equipped than the old one, is now under construction for sugar courses in the College. It will probably be finished in time for the use of the sugar technology II students. When completed, it will consist of a cane weigher, a 20 H. P. boiler fired by a green bagasse furnace, a six roller mill, pumps, defecators, settling tanks, open evaporators, a vacuum pan of about two-picul capacity, crystallizers, filter press and centrifuge. In addition, it will have an up-to-date model sugar laboratory. The mill will have a capacity of five piculs daily.

New courses in Soil Technology just approved by the University Council are: Agronomy 22, *Elementary Soils*; Agronomy 23, *Soil Physics and Management*; Agronomy 24, *Soil Biology*; and Agronomy 25, *Soil Fertility*.

UNIVERSITY OF THE PHILIPPINES

COLLEGE OF AGRICULTURE

Course in Sugar Technology

Pre-requisite.—Students registering in sugar technology shall have completed a four-year high school course including 14 units as follows: *Algebra*, 1½; *Plane Geometry*,1; *English*, 3; *History*, 1; *Biology*, 1; *Physics*, 1; and *Electives*, 5½.

Curriculum.—The curriculum in sugar technology consists of the following subjects and credit hours:

Year	SUBJECT	Credit hours	
		1st Sem.	2nd Sem.
I	Chemistry 1	5	5
	Plant Physiology 4.	5	5
	Spanish 1	3	3
	Agronomy 1	2	2
	Entomology 1	5	
	Mathematics 4		3
Summer	Mathematics 6	5	
II	Chemistry 2	5	5
	Chemistry 3	5	5
	Spanish 2	3	3
	Agronomy 3	5	
	Agronomy 22		5
	Economics 2	3	3
III	Chemistry 4	5	5
	Chemistry 5	5	
	Chemistry 6		5
	Plant Pathology 1.		5
	Mathematics 7	5	
	Rural Engineering 1.	5	5
Summer	Chemistry 11*a*	5	
IV	Chemistry 7	5	
	Agronomy 11		5
	Animal Husbandry 1	5	5
	Engineering 3	5	
	Engineering 4		5
	Elective	5	5
Summer	Chemistry 11*b*	5	
V	Chemistry 8		5
	Chemistry 9	1	1
	Chemistry 10	8	5
	Agronomy 18	5	
	Agronomy 19		5
	Agronomy 25	5	
	Economics 5		3

Military drill and physical training.—With other students of the University, students in sugar technology are required to attend military drill three hours weekly throughout the first two years, and physical training one hour weekly throughout the first year of residence.

Degree.—The University of the Philippines confers the degree of *Bachelor of Science in Agriculture* and a *Certificate in Sugar Technology* upon students who satisfactorily complete the course.

Further information.—Applicants for registration and others interested may obtain further information from the *Dean, College of Agriculture, Los Baños College, Laguna, P. I.*